AD

REPORT 26-03-R-012

INTEGRATION

(PHASE 3D)

FINAL TECHNICAL REPORT

by

A N Schofield and R S Steedman

1 September 1995

United States Army

EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY

London England

CONTRACT NUMBER N68171-94-C-9066

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Title of Proposal:	Phase 3D: Integration
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A N Schofield R S Steedman 1 September 1995

SUMMARY

Discussions with each of the Laboratories participating in the demonstration experiments have clarified the nature of the first experiments that will be carried out following commissioning. Staffing of the centrifuge centre has been considered in detail and the requirements for technicians and engineers to support researchers preparing and conducting model tests are being planned together with ANS&A support during the period of the demonstration tests.

It is envisaged that an ANS&A Associate will be resident in Vicksburg during and following the installation and commissioning of the centrifuge. The delays in the completion of the centrifuge in France during 1995 will postpone the initial research experiments into 1996.

It is recommended that a number of experienced staff are appointed to act as centrifuge engineers; these should be experienced individuals who are authorised to approve proposals for model tests. The role of centrifuge engineer is defined in procedures for the safe operation of the centrifuge which are presented in this report; these have been developed by ANS&A based on experience at Cambridge and define the key roles of the centrifuge engineer, centrifuge user and centrifuge operator.

The appointment and training of operators and technicians who are experienced in the preparation and instrumentation of physical models is also urgently required. A core team of staff will be required full-time at the centrifuge facility to assist with the extensive model testing programme that will be necessary to complete the planned demonstration experiments.

Each flight of the centrifuge is classified as either a 'proof test' or a routine operation and this dictates the level of documentation required to be checked by the operator before the test is initiated. In the event that the test requires the first load of an appurtenance, or the loading of an appurtenance to a new g level, that test is defined as a proof test and particular requirements are placed on the user and the engineer to demonstrate the safety of the facility and of the experiment.

LIST OF KEYWORDS

centrifuge
test
model
capabilities
research
quality
assurance
containment
buildings
equipment
appurtenances
instrumentation
safety

CONTENTS

1.0 DEVELOPMENT OF RESEARCH CAPABILITIES

1.1 RESEARCH BACKGROUND

This report is one of a series of reports prepared by Andrew N Schofield & Associates Ltd (ANS&A) addressing the development and commissioning of new capabilities for physical modeling research at the Waterways Experiment Station (WES), through the acquisition of a powerful centrifuge facility. The research described herein forms Phase 3D of the programme of work first proposed under ANS&A's response (of 17 April 1989) to the WES Broad Agency Announcement (BAA) of December 1988.

Phase 1 of this project, entitled "Safety Factor Analysis for Centrifuge Systems", addressed the specification, Quality Assurance (QA) procedures and safety of operations that would be required to successfully commission a new centrifuge center at WES. In the Final Technical Report under Phase 1 (Contract Number DAJA45-90-C-018), ANS&A (1992), it was recommended that WES should buy the Acutronic 684-1 centrifuge subject to the implementation of QA procedures designed to ensure the swift integration of the new facility into the research activities of WES, Schofield and Steedman (1991).

Phase 2 of this project (Contract number DAJA45-91-C-0012) entitled "Development of a WES Centrifuge" initiated the Quality Assurance process under which ANS&A worked with the Laboratories of the US Army Corps of Engineers through the Centrifuge Coordinating Committee to prepare specifications for appurtenances and data aquisition equipment that would be needed during the commissioning of capabilities. ANS&A's Phase 2 Final Technical Report made specific recommendations concerning the development of appurtenances for initial experiments which would be compatible with the design of the Acutronic 684-1 centrifuge, Schofield and Steedman (1992).

Phase 3A entitled "Centrifuge facility design and development of capabilities" (Contract number DAJA45-91-C-0025) and 3B "Report on Quality Assurance for the WES Centrifuge" (Contract number DAJA45-92-C-0021) addressed the continuing role of ANS&A in providing advice and guidance during the design phase of the WES Centrifuge by Acutronic France SA. ANS&A's Final Technical Report covering Phases 3A and 3B recommended acceptance of the detailed design of the Acutronic 684-1 centrifuge and that the operating envelope of the centrifuge be revised to maximise the potential capability of the facility in the mid-range of operating levels (150-350g), Schofield and Steedman (1993).

Phase 3C, entitled "Coordination of operations for centrifuge quality control" (Contract number DAJA45-93-C-0021), presented recommendations concerning the initial research experimentation on the WES centrifuge and addressed in detail the mechanical commissioning of the centrifuge following its arrival in Vicksburg. A key recommendation arising from Phase 3C was the separation of the initial mechanical commissioning (upto a level of around 250 gravities) from the final commissioning (to full capability) and the necessity for careful and close control of the commissioning operations, Schofield and Steedman (1995). This approach was considered essential because of the unique nature of the centrifuge and the uncertainty over the available Manufacturer's documentation concerning Quality Control.

In the current Phase 3D entitled "Integration" reviews with each of the Laboratories hav been held to finalise their plans for demonstration experiments. The final phase of the centrifuge assembly in France has been discussed with Acutronic to ensure that inspections can be carried out in France during key operations. Appurtenance development in the UK has also been closely monitored and the development of specifications for equipment items has been reviewed with CIEL engineers to ensure these will provide appropriate capabilities in each field. Recommendations have been prepared concerning the Operating Procedures for the centrifuge which will be adopted following commissioning and these are appended to this report.

1.2 DEMONSTRATION EXPERIMENTS

The demonstration experiments to be carried out in 1995 and 1996 are in the process of being defined in discussion with each of the Laboratories at WES and the Cold Regions Laboratory. They are expected to include:

a) explosions in rock chambers;
b) explosions in layered soils;
c) beach profile formation;
d) flow of immiscible fluids in partially saturated and saturated soils;
e) stability of capped dredge disposal, migration of heavy metal contaminants;
f) failure of silt slopes;
g) earthquake stability of dams on deep sediments;
h) penetration of multi-year sea ice;
i) frozen ground.

This review has led to a careful appraisal of the needs for equipment and appurtenances being developed in Cambridge for the initial experiments.

1.3 RECORDS OF DISCUSSIONS

Under ANS&A's Quality Plan all meetings are documented and used to provide a record of progress on the project. The meeting notes cover the discussions with each Laboratory on future capabilities and opportunities in some detail and describe meetings at WES, in France and in the UK relevant to the project; notes appended to this report continue the sequence of meeting notes from the Phase 3C Final Technical Report and cover the period 1 January 1994 to 1 November 1994.

2.0 STAFFING REQUIREMENTS

2.1 STAFF APPOINTMENTS

The initial staffing of the centrifuge center is now being addressed. This will depend in part on the location of the centrifuge center within the WES Laboratory management structure (which is yet to be finalised) but will, of necessity, include certain key positions; discussions concerning these positions have been held with WES staff over a period of several months.

In the critical role of centrifuge engineer ANS&A have identified a number of potential Associates who could fulfill the responsibilities of this key position in the period following the mechanical commissioning of the centrifuge. Following discussions on the availability and experience of several individuals, ANS&A now recommends that Dr Kevin Stone be based in Vicksburg for around one year, commencing during the installation of the centrifuge and continuing during the period of the demonstration experiments, which he would supervise. Dr Stone has extensive experience of the operation of centrifuge facilities, having worked at the Cambridge University, University of the Ruhr at Bochum and University of Western Australia at Perth facilities. The UWA centrifuge where Dr Stone was most recently based is an Acutronic 661 model with many similar characteristics to the new WES Acutronic 684-1 centrifuge.

Staffing of the centrifuge centre will also require full-time mechanical and electronic engineer and technician support. A potential electronic technician for the centre has been identified from ISD; a mechanical engineer has still to be selected from the WES staff. Other technicians will be needed with experience of model building and sample preparation. It is likely that these will be found in the Geotechnical Laboratory itself.

A key appointment to the centrifuge facility will be the position of manager or director. A decision on the management structure of the centrifuge centre will facilitate the coordination of operations during the commissioning of the centrifuge and the development of capabilities that will follow; ANS&A recommend that this decision is now urgently addressed by WES.

2.2 TRAINING

Research workers who are potential future users of the new centrifuge will require training in the application of the centrifuge to field problems as well as in experimental procedures. A review of possible demonstration experiments has been held with Cold Regions Laboratory and with the Geotechnical Laboratory and these will be used as a basis for training and the development of operating procedures. Each experiment will require a statement of technical justification in addition to calculations of record which confirm the safety of the equipment and these will be developed with the prospective users as an integral part of the training process.

A program of training sessions at WES is recommended to address key aspects of centrifuge theory, application, mechanical principles and experimental technique. These sessions would be presented by ANS&A and could involve invited presentations by academic and other experts.

3.0 OPERATING PROCEDURES FOR THE ACUTRONIC 684-1 CENTRIFUGE

Appended to this report are Draft Operating Procedures for the WES Centrifuge. These describe in detail the responsibilities of individual posts, such as Centrifuge Engineer and Centrifuge Operator, and define the process which must be followed in the design of a centrifuge experiment, its approval for flight and the control of the centrifuge flight itself.

Once accepted and issued by the WES centrifuge director/manager, these Procedures must be enacted as mandatory by all staff. Experience of the safe operation of other centrifuge facilities suggests that during moments of rapid decision or crisis, the clear demarcation of responsibility established in such procedures will minimise the risk of accident to individuals, the facility or the experiment.

The Procedures define clearly the principle of the proof test. Best practice at major centrifuge centers has been based on the use of proof tests of complete components to ensure their safe use at a lower working level. It is considered that because of the complexity of the equipment this approach is the only valid approach to assure the quality of any item of equipment, including the centrifuge itself. However, as the centrifuge may not be overloaded beyond the maximum operating envelope it is proposed instead that a working envelope be defined within the maximum envelope within which model packages may be operated (once they themselves have been proven to the higher stress level) with a less stringent requirement for the user to demonstrate the safety of their package. Thus considerable emphasis is placed on the proof test as the main technique for verifying the design and manufacture quality of all equipment items.

As described in the Final Technical Report under Phase 3C, ANS&A recommends that this approach is adopted for the centrifuge itself, as the principle means by which conformance of the centrifuge to specification is achieved. This will require close monitoring during the mechanical assembly and initial operation to ensure that the working envelope of the centrifuge is developed in a staged and careful manner. Other forms of load test of the machine are unlikely to be successful because of the large size of the individual components and the importance of self weight as a component of the internal stress distribution.

REFERENCES

Schofield, A.N. and Steedman, R.S. (1992) Development of a WES Centrifuge, Final Technical Report, ANS&A Report 26-02-R-004 for US Army European Research Office, London (Contract No. DAJA45-91-C-0012).

Schofield, A.N. and Steedman, R.S. (1991) Safety Factor Analysis for Centrifuge Systems, Final Technical Report, ANS&A Report 26-01-R-001 for US Army European Research Office, London (Contract No. DAJA45-90-C-018).

Schofield, A.N. and Steedman, R.S. (1993) Design of the WES Centrifuge (Phases 3A & 3B), Final Technical Report, ANS&A Report 26-03-R-006 for US Army European Research Office, London (Contract No. DAJA45-92-C-0021).

Schofield, A.N. and Steedman, R.S. (1995) Coordination of operations for centrifuge quality control (Phase 3C), Final Technical Report, ANS&A Report 26-03-R-009 for US Army European Research Office, London (Contract No. DAJA45-93-C-0021).

APPENDIX A

Records of meetings

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-100
Present:	RSS, RHL, Neil Baker	Date:	4 January 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge status		

The new Contracting Officer's Representative on the contract with Acutronic USA Inc. (DACA39 92-C-0016) will be Mr J Huie, following the retirement of Mr G P Hale. JH is Chief of the Rock Mechanics Branch of the Soil and Rock Mechanics Division. He has been involved with centrifuge testing at Colorado with Don Banks.

Documentation and specifications to accompany the new data aquisition system were reviewed by Neil Baker. The need for office space for ANS&A to store information and tools was noted.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-101
Present:	RSS, RHL, Neil Baker, WM	Date:	4 January 1994
		Time:	9.30 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Mr Marcuson confirmed that G P Hale had retired and that J Huie had been appointed Contracting Officer's Representative.

A manager for the inaugural conference was to be appointed shortly. The invited conference would be a presentation of WES experiments conducted during ANS&A's commissioning period. It would probably be limited to one day.

A second 10 foot diameter Government Surplus centrifuge had been identified. Its future was undecided, although one option was to donate it to a University for research purposes.

Gary Butler, a graduate mechanical engineer who had been working at the Geotech Lab in 1993, was expecting to travel to Cambridge during the summer of 1994 to gain experience in centrifuge testing.

Funding for the development of appurtenances in FY94 had been delayed but was anticipated to arrive later in the month.

Staffing for the centrifuge was still under consideration. It was recognised that a mechanical engineer and an electronics engineer would be needed full-time at least. Specialist expertise in high speed data aquisition and the use of high speed cameras was available on the Station. It may become necessary to purchase a high speed camera for the centrifuge.

It was noted that as training needs evolved ANS&A would consider carefully which Associates would be most appropriate to assist in the commissioning of capabilities at each stage and would make the necessary arrangements to ensure that this was achieved. A training plan for the use of the Schaevitz centrifuge was to be developed by WES.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-102
Present:	RSS, RHL, Neil Baker, PG	Date:	4 January 1994
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	The Schaevitz Training Centrifuge		

Mr Paul Gilbert and Mr Tom McEwan demonstrated the operation of the Schaevitz centrifuge to 200 rpm (38g).

The Schaevitz G-E-4 centrifuge has a nominal diameter of 2m and top speed of 400 rpm although circuitry had been designed and installed whilst the centrifuge was in use at the Picatinny Arsenal to limit the arm speed to 150 rpm. This had been overcome and a small payload, comprising a transducer and mount weighing approximately 0.2 lbs had been accelerated to a maximum of 250 rpm (around 60g) in a trial experiment. Operation had been found to be smooth and vibration free. The permanent slip ring assembly on the machine consists of 120 individual lines with connector panels on and off-arm.

Drawings of the arm would be given to ANS&A by WES. Two memoranda for record had been issued, dated 4 November 1993 and 3 January 1994, concerning the Schaevitz centrifuge and its operation.

NB demonstrated the use of the ANS&A mobile data aquisition system. At subsequent sessions, the new data aquisition system was used in conjunction with simple control tests using the Schaevitz.

The appurtenance crates in the warehouse were inspected.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-103
Present:	RSS, RHL, Neil Baker, PG, TM, ISD staff	Date:	5 January 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Electrical services		

RHL briefed the meeting on the design and construction of the centrifuge facility and the power systems that will be supplied to the building. Signal conditioning and data aquisition systems were discussed. Concern was expressed over the length of the cable runs and possible losses between different access points.

The current specification in the model prep room was noted to be 120 or 240 V single phase; provision for 240 V three phase was not shown on the drawings. It was suggested that a spare connector providing 480 V three phase on panel PD could be used with a transformer to provide 240 V three phase in the prep room. This would be discussed with Acutronic USA.

480 V three phase would be required on arm.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-104
Present:	RSS, RHL, Neil Baker,	Date:	5 January 1994
	J Huie, R Mead	Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Briefing on BAA and centrifuge progress		

Following the appointment on Jerry Huie as the Contracting Officer's Representative on the contract with Acutronic USA (DACA39 92-C-0016), announced on 4 January 1994, RSS briefed Mr Huie on the project and the background to ANS&A's response to the WES BAA. RSS discussed ANS&A's research role in the demonstration of capabilities and in providing technical support for WES in their purchase of the Acutronic centrifuge. The status of the appurtenances, centrifuge fabrication and construction of the containment structure was noted.

Concern was expressed over the quality of data aquisition facilities which were being used in certain university facilities. It was agreed that close interaction between WES electronic engineers and ANS&A should ensure that these were taken into account in the design and development of new equipment for WES.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-105
Present:	RSS, Neil Baker, Mr Ona,	Date:	19 January 1994
	(later JN-F, JP)	Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

Slip ring stack

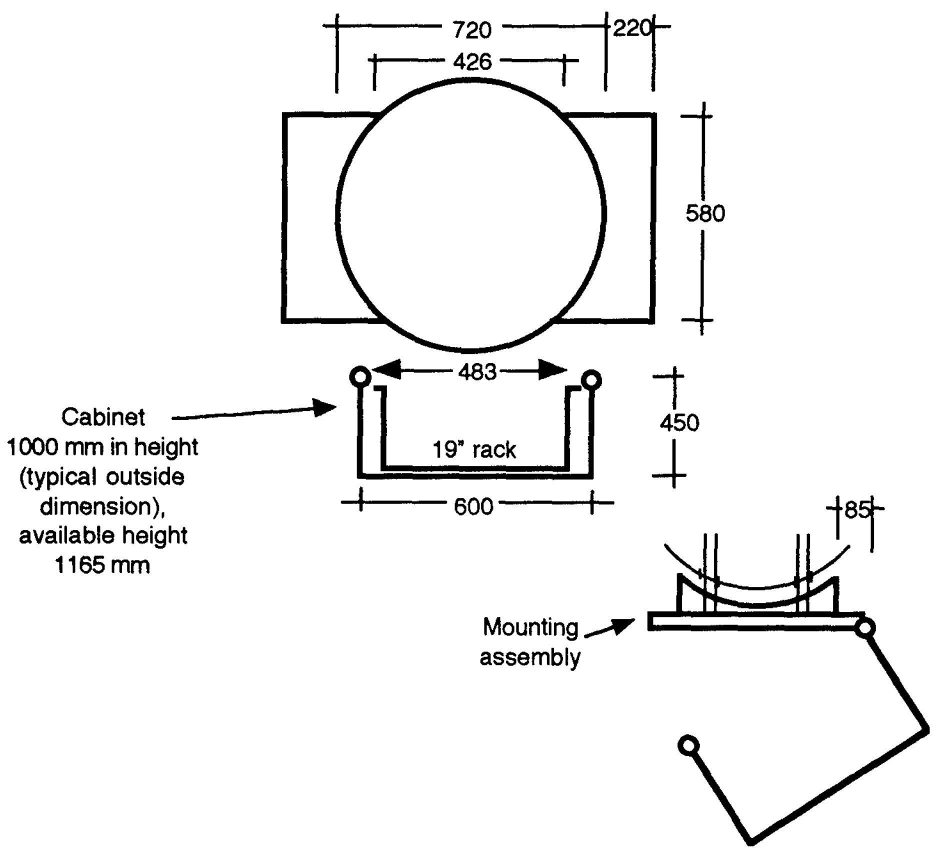
Spare lines in the slip ring stack will be tied up in the capsule. Space will be provided for additional connectors for users to wire up any spare lines in future if required. Spare lines may provide opportunity for additional video channels (3 lines needed per channel).

Power on arm

Acutronic supplies 660 V 3 phase, transformed to 410 V (five wire) in their cabinet 684-10-006A. The on board power is limited to 80A by use of European standard components.

Central arm services

The design of cabinets to be mounted at the centre of the arm was discussed and the mechanical drawings and component catalogues inspected to check dimensions:



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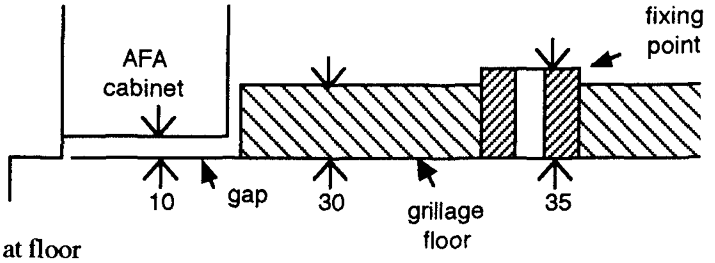
It was noted that the access door to view the servo-valve for balancing must be accessible; this will be left open once the cabinets have been fitted and used for power lines (to be wired by ANS&A) running from the power bus to the user cabinet. Two higher openings will be cut above the access door for cable runs between the two cabinets. The access door is located on the lefthand side of the circular stack looking from the swing towards the centre of the arm. Holes for tension rods will be drilled prior to assembly.



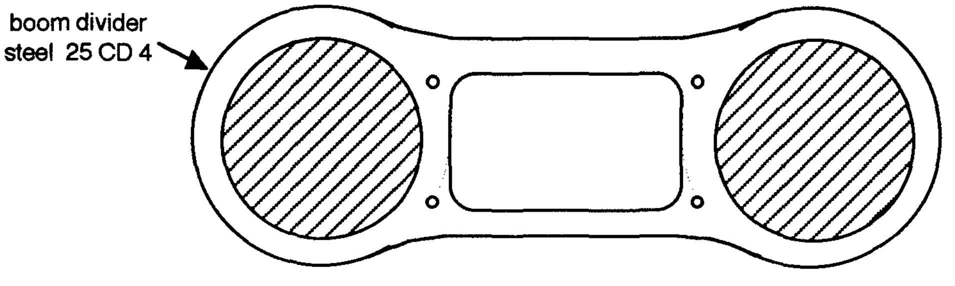
Detail at floor

User cabinet

ANS&A to consider providing duplicate mount for AFA connector panels. ANS&A would remove AFA panel and mount in user cabinet.

Termination panels

AFA propose mounting points on straps (to be defined before May), 16 No. on each hanger. Cable trays will be supported on beams at each by boom divider. Cable trays are perforated. At the end of the trays they are open and sit on beams spanning across the boom divider. The beams have been sized to carry the radial force from the selfweight of the cables and tray. This may not be adequate to support termination panels and a new saddle could be mounted on the boom divider susupended from four bolts, one in each corner. Alternative options were considered such as hanging the saddle from the boom divider. ANS&A will specify clearance holes in the boom divider for AFA.



At the centre of the arm, the cable trays terminate against the drive box. Three cable support rails will be fixed on the drive box under the grillage floor for Acutronic and ANS&A services. The grillage in the floor has dimensions 40 x 40mm.

The hydraulic passages are about 3.5m in length from the rotary joint to the user connections at the centre of the arm, all hose (except for the metal joint). The joint specification is 2 at 200 bar (oil) and 4 at 20 bar (air or water). The joint is nickel plated steel with seals made from teflon/carbon composite with a rubber O ring. Special seals were provided for CCORE.

Programme

The delay to 15 May in the draft Acutronic programme is due to delays in funding. Intermittent funding has caused stop-start progress on machining and other fabrication activities.

Shroud

Difficulties with the old rear shroud at Takenaka were avoided by construction of a new one.

Commissioning was completed at Takenaka in December. RSS will visit Courtalds in France at the end of February to meet their design engineers and to discuss their design calculations.

Design Review

Design review of Acutronic's work would best be undertaken at AFA's offices. This would focus on the as-built calculations in conjunction with the as-built drawings.

Control of manufacture

J-FC will discuss with AFA a review of manufacture control procedures during the fabrication and assembly stages. RSS will visit the TLM plant to inspect the platform during fabrication.

Commissioning test plan

AFA will prepare and submit their test plan shortly.

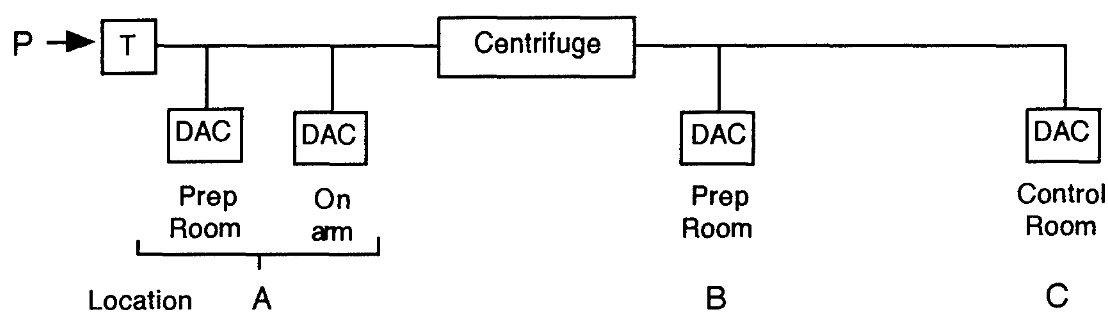
Factory inspections

AFA will advise RSS and J-FC of key stages during the manufacture process during which visits may be useful.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-106
Present:	RSS, RHL, JH, H Greer	Date:	10 March 1994
		Time:	8.30 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Electronic systems		

The calibration of gauges was noted to be a concern and it was important to establish the same reading at different locations. This is achieved by using a scale factor for each location based on check out of fixed lines. The calibration of the gauges is deduced separately.



The capability of shunt calibration at 1g is required at the junction box, ie. access to power and signal line pre-amplifiers using terminal lugs or similar. Potentiometers on PCBs in the junction box should also be considered. It should be anticipated that ISD will provide test equipment to carry out AC voltage substitution and other testing. A meeting with RSS and Neil Baker would be needed to review progress on specifications for the second phase of data aquisition equipment.

Some experimenters were concerned over the possible influence of gravity on their measuring devices. It was recommended that this be isolated by specially designed experiments.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-107
Present:	See below	Date:	10 March 1994
		Time:	1 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Briefing on centrifuge		

The briefing was attended by the following representatives from ANS&A, WES, Acutronic USA and Bounds Construction Company.

Name	Affilation
R S Steedman	ANS&A
R H Ledbetter	WES - GL
W F Marcuson III	WES - GL
J Huie	WES - GL
G Hale	Retired
B Logue	WES
H Voss	Acutronic USA
D Collins	Acutronic USA
R Austin	Johnson-McAdams
R L Bounds	Bounds Construction Co
R McMillan	Bounds Construction Co

S Ragan and K Saucier (WES - SL) joined the meeting later.

The building facility was anticipated to be complete by Mid-March 1995. However as it would not be desirable to bring the centrifuge into the area until the building was ready to accept it, the building was therefore regarded as now dominating the programme. Bounds and Johnson-McAdams were expected to hold an on-site meeting to review progress shortly (20-25 March). Space had been identified as a potential problem.

Transportation of the centrifuge may now commence in November; transportation and installation times was now estimated to be considerably less than planned in original Acutronic programme.

It was agreed that a summary programme would be prepared by Acutronic USA with key dates, identifying critical path items, to be delivered in two weeks time.

Performance and quality on the construction site were generally considered to be satisfactory to date but the concrete on top of the motor foundation had been cored to monitor strength build-up. Some concrete had been rejected and a problem with air content had not yet been defined. (Concrete was being supplied by Mississippi Materials.)

Concern was expressed over the maximum temperature of the concrete permitted in the specification and the difficulty with meeting this in long pours during daytime. The use of techniques to keep the concrete temperature within specification were discussed, including crushed ice, chilled water, fly-ash and liquid nitrogen.

The site was then visited. Reinforcement cages were being fixed around the large diameter air vents in the floor of the centrifuge chamber.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-108
Present:	RSS, RHL, B Logue,	Date:	10 March 1994
	H Voss, D Collins	Time:	3 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Contractural issues		

The issue of cost changes over the original Acutronic estimate was discussed.

A modification to the contract to alter the date of completion would be required in due course. The current position was that although February 15 was known to be too early the actual completion date cannot be determined until the new consolidated programme is completed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-109
Present:	RSS, WFM III	Date:	11 March 1994
		Time:	8 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Technical support for the new centrifuge centre and the provision of mechanical and electronic engineer staff were discussed. Candidates were being identified for these positions.

The development of a training plan to make use of the Schaevitz training centrifuge was discussed.

It was agreed that an internal meeting within Geotech Lab of experimenters would be held soon to discuss the demonstration tests to be run during 1995.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-110
Present:	RSS, P Gilbert	Date:	11 March 1994
		Time:	8.30 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

The development of the initial data aquisition systems for the centrifuge was discussed and in particular techniques for shunt calibration, setting offsets and testing of the electronic system.

It was noted that different scale factors would need to be established at different locations and agreed that the list of desirable features included (in order of priority) :

1) shunt calibration at 1g;
2) setting offsets at 1g;
3) resetting offsets at high g;
4) shunt calibration at high g.

It was agreed that 3) and 4) may only be achieved in the long term.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-111
Present:	RSS, RHL, JH, H Voss,	Date:	11 March 1994
	D Collins	Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Air pads		

The meeting discussed the use of air pad systems or skate systems to move packages around the Prep Room floor.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-112
Present:	RSS, RHL	Date:	11 March 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

The anticipated visit by Gary Butler, a post-graduate student of mechanical engineering, to Cambridge during the summer of 1994 was discussed.

RSS would discuss with Acutronic the commissioning of the centrifuge, including the instrumentation of the platform and the programme.

Neil Baker would submit the draft documentation on the Phase I data aquisition system and the plans for the Phase II on board system as soon as possible. It was expected that NB would need to visit WES during the summer of 1994 to interact with ISL. Several weeks would need to be allowed for WES to review the documents prior to finalising them.

Options for the development of an earthquake shaker would be reviewed by RSS.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-113
Present:	RSS, Mr Aubry (Courtaulds),	Date:	16 March 1994
	Mr C Loth (AFA)	Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Rouen
Subject:	Design and fabrication of the aerodynamic shroud		

RSS visited Courtaulds to discuss the design and fabrication of the aerodynamic shroud for the WES centrifuge, accompanied by Mr Loth of Acutronic France.

The finite element analysis for the shrouds for the Takenaka centrifuge and the WES centrifuge had been subcontracted by Courtaulds in November 1992. This analysis formed the basis of the design. Mr Aubry, Chief Engineer for Courtaulds, was then working for the subcontractor.

Following the failure of the front shroud on the Takenaka centrifuge in Japan in 1993, the design was recalculated in-house at Courtaulds and the front shroud rebuilt. No FE computations were made. A buckling calculation was run, however, using the same FE model. This was reviewed and it was noted that the stresses in this calculation appeared low and would be checked by Courtaulds.

The failure mechanism of the front shroud and rear shroud of the Takenaka centrifuge was discussed at length.

The problem of short wavelength buckling, "the wrinkling stress", was discussed in detail and contrasted with panel buckling. Concern was expressed over the performance of composite materials loaded in-plane by self-weight and over the difficulties of analysing the design.

The new concept shroud for WES was inspected and changes to the original design noted. A beam now encircles the shroud where it attaches to the swing straps encased in carbon fibre. The rear shroud has also been reinforced at its internal corners with carbon fibre. No formal design calculations were available. Drawings of the new design were received.

Although it was agreed that the new concept shroud appeared to be considerably stronger than the original design RSS explained that it would be necessary to demonstrate by calculation or experiment that the required factor of safety against failure had been met. It was stressed that no design report had been received for the new design. The possibility of a full scale test of the original WES shroud was discussed using static loading.

It was agreed that test panels cut from the old shroud would be tested in compression by Courtaulds to establish the wrinkling stress for the shroud wall panels and to compare the experimental data with the design value and textbook solutions. Tests would be done on samples from the old and new shrouds (using samples made at the same time and cured by the same process). Courtaulds would prepare a brief report to summarise the experiments and to contrast the findings with analytical and numerical solutions.

A report of the meeting would be prepared by ANS&A and a copy provided to Courtaulds through Acutronic.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-114
Present:	RSS, ANS, NB, CS	Date:	21 March 1994
		Time:	4 pm
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Appurtenances		

Commissioning of the centrifuge

The recent visit by RSS to Rouen was discussed and the importance of the commissioning tests noted. Acutronic were expected to deliver a commissioning test plan shortly and it may be recommended that this includes separate tests of the platform with and without the shroud.

ANS&A expect to oversee the Acutronic commissioning. Together with WES it will be necessary to have mechanical and electrical engineering capability on site in addition to an expert in electronic systems. NB and a support engineer will expect to spend around two weeks in Vicksburg wiring up the user systems and reviewing the Acutronic work. RSS would also expect to visit during this period.

Demonstration experiments

Following handover to ANS&A/WES NB will return to oversee the first experiments on the centrifuge. This may comprise a blast test in dry sand.

Based on current available information, the demonstration experiments to be carried out during 1995 were then discussed :

Laboratory	Experiment	ANS&A Associate	Researcher
Cold Regions	Permafrost	C C Smith	
Hydraulics	Groundwater	C Savvidou	
Coastal		Shallow harbour	R S Steedman
Structures	Shotgun magazine	R S Steedman	
Geotechnical	Clay with penetrometer	M D Bolton	
	Earthquake	R S Steedman	Gopal
Environmental	Wetlands	C Savvidou	Potter, Gopal
Information	Retaining wall	M D Bolton	

Progress with appurtenances was also discussed:

Reference	Subject	Associate	Support	Contact
EQUIP-5	Thermal chamber	C C Smith	C Savvidou	S Ketcham
EQUIP-6a	Plane strain box	M Gopal	C Savvidou	
EQUIP-6b	Loading actuator	M Gopal	M D Bolton, N Taylor	
EQUIP-7	Consolidometer	N Taylor	R S Steedman	
EQUIP-8	Control system	N Taylor	R S Steedman	
EQUIP-9	Data aquisition Phase II	N Baker	R S Steedman	H Greer

Draft specifications were in preparation and expected to be completed for most appurtenances during April. Design work had commenced on the thermal chamber and data aquisition systems.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-115
Present:	RSS, ANS, NB, KW	Date:	15 April 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Appurtenances		

Central arm services

The design of appurtenances and services on board was discussed and a number of points were noted to be resolved with Acutronic as soon as possible:

a) the capacity of the hydraulic joints with regard to air flow[1];
b) the provision of a matrix of four 20mm clearance holes on the outer boom divider sufficient to carry around 50kg total (or around 4 tonnes per hole at high g) on M20 bolts;
c) mounting holes through the slip ring unit would be needed to support ANS&A central arm service cabinets. These should be 30mm diameter clearance holes to carry 4 tension rods and 2 cable conduits 30.5mm in diameter.
d) The provision of termination panels on the swing should be addressed shortly.

Consolidometer

The design of the consolidometer was progressing. A Parker jack (US) would be supplied with a capacity of 150 tonnes and a 1m stroke. This would provide overpressures of 1.3 MPa on the large 1200mm tub, 2.6 MPa on the standard 850mm tub and 10.6 MPa on the 420mm tub. The consolidometer will be capable of consolidating into the plane strain box with or without a liner (appropriate liners will be supplied this year). Downward hydraulic gradient will be necessary for the circular chamber. The control system will be similar to the LNEC system supplied for the Lisbon centrifuge.

Plane Strain Box

Expected to be 400mm internal width. The length will be finalised depending on the requirements for lagging. The height will be a maximum for the available headroom. The dimensions should be finalised in around two weeks time. The box will have the capability of active thermal control to provide a constant temperature condition in the model. A liner will be supplied to enable models to be removed easily afterwards.

Loading actuator

A realistic specification is under development defining the degrees of freedom, control system and travel capability. It was noted that it may be possible to utilise the penetrometer control system. A titanium bridge will be supplied to support the actuator and the penetrometer.

Cold regions/thermal chamber

The thermal chamber will be a standard 850mm internal diameter with thick walls, lagged to provide a thermal (but not chemical) boundary. The upper and lower boundaries would have active thermal control such that a thermal gradient could be established through the model. Insulation would be needed between the chamber base and the platform. RSS to discuss with CCS the boundary conditions for the thermal chamber.

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Environmental test chamber

As a precursor to the design of the large thermal chamber, a smaller 420mm diameter environmental test chamber will be fabricated. This will have chemically inert plating on the chamber walls with provision for active cooling. The lid and base will be insulated to enable a constant temperature to be maintained in the model.

Data aquisition system Phase II

The onboard data aquisition system will comprise 48 channels (with architecture for 72 channels) sampled using a 100 kHz card. A 1 MHz card will be available over 4 channels providing several higher speed lines. Offsetting and calibration facilities will be provided. The full specification will be issued to WES for comment shortly.

Specifications for all other equipment are expected to be completed by the end of April with the exception of the loading actuator and consolidometer control system which will be completed by the end of May.

1 Information subsequently received from Acutronic on April 26 confirmed that the capacity of the rotary joint was 1 standard or 'normal' cubic metre per minute (volume flow rate at 1 bar pressure) per joint, including an allowance for a 0.5 bar pressure drop inside the rotary joint and hydraulic lines on-axis. This compared favourably with the predicted requirement for air flow of around 50 scfm total (or 1.4 standard cubic metres per minute).

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-116
Present:	RSS, RHL	Date:	27 April 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

General

Discussed air flow provision on centrifuge through hydraulic joint. Contacted Acutronic to confirm their fax of April 26. The maximum air flow[1] through each rotary joint is 1 standard cubic metre per minute (standard cubic metre = volume at 1 bar pressure).

The final dates for Gary Butler's visit to Cambridge were agreed as 30 May to 15 August 1994. If a visit to Acutronic was made during that time, then it would be desirable for GB to attend.

The site was visited and photographed. Gravel was being backfilled around the foundation block.

Programme

The Summary Programme had been received by WES from Acutronic. Acutronic's contract would be amended to show the May 15 date although they had expressed confidence in still meeting the March 15 goal for handover. This was explained by their expectation of a shorter transportation period than programmed, with the possibility of the centrifuge arriving in Vicksburg in December 1994 rather than January 1995. The demonstration tests would take place over at least a six month period following the handover, leading up to the inaugural conference in November 1995.

A meeting for GL to discuss geotechnical testing was fixed tentatively for the week commencing 18 July. This could be combined with a visit to CRREL with ANS. The timing for potential a visit to France to attend the factory acceptance test in Paris was discussed. Possible dates included 6, 7 September or week commencing 17 October. The nature of the presentation of the paper on the WES centrifuge at the Singapore Conference Centrifuge '94 was agreed. It was expected that RHL, RSS, ANS and JCC would be attending.

Demonstration of capabilities

Further discussions with Coastal Lab, Hydraulics Lab and Environmental Lab are needed to finalise demonstration experiments.

Pre-proposals for the GL demonstration tests have been solicited by Dr Hadala. An earthquake test is desirable; initial tests may be to investigate $K\sigma$ and subsequently effects of residual shear stress factor $K\alpha$. These free field tests would ideally be at low g ($\approx 50g$) with a model specimen around 900 mm deep (140' prototype). The model would propagate shear waves through around 100' of foundation and then through 25' of liquefiable layer and 15' overburden. This depth of free field would be unique for previous centrifuge

1 This was subsequently revised by Acutronic in a fax received on June 2. Based on new information from their supplier TECMECA the rotary joint performance was quoted as 2 Nm^3/mn (normalised cubic metre per minute) at 20 bars, dropping to 0.8 Nm^3/mn at 10 bars.

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tests and the low g would provide sufficient detail in the liquefiable layer to place several transducers. Future work during FY96 would investigate the behaviour of embankments on top of deep foundations using higher g levels.

The early development of a shaker for demonstration tests would therefore aim to shake a large deep model at modest g levels. A high g capability would follow. The container would need to be capable of sustaining high g to enable overconsolidation of specimens in flight.

The shaker and the containment structure should be independent. The shaker could be low g rated and the container high g. Different containers may be needed for testing at different g levels. Future research would investigate development of slip mechanisms in soft deposits, potential remedial measures etc. The containment structure should be capable of supporting a loading actuator for post-earthquake footing tests.

The initial demonstration tests would comprise a deep soft foundation supporting an embankment. The depth of the model may permit new mechanisms of movement to develop. A second experiment could be the reponse of lined/capped disposal storage area (eg a clay lined disposal area with sludge).

Other demonstration tests in geotechnical engineering were also discussed which would utilise field soils and the consolidometer.

Appurtenances

The cold regions (thermal chamber) is envisaged as 850 mm diameter with the capability of gradient control between top and bottom boundaries with insulated side walls. The inner surface would not be chemically inert as this would be inconsistent with the insulated walls.

A small environmental test chamber (420 mm inner diameter) is anticipated to provide thermal control of the side walls with a chemically inert inner surface and external lagging. The small diameter will enable high overpressures to be achieved using the consolidometer.

The dimensions of the plane strain box are still to be determined. The liners will be designed to be used with the consolidometer. The box will have a circular window and an internal width of approximately 400 mm. A realistic specification for a loading actuator is being developed at present which will consider degrees of freedom, travel limitations etc. but it was noted that the final specification should await the definition of a suitable research experiment. A titanium bridge has been designed to carry equipment (including the penetrometer) at upto 350 g which will operate on the plane strain, 850 and 1200 mm tubs.

The consolidometer and control system will use a 150 tonne jack capable of giving overpressures of around 1.3 MPa in the 1200 mm tub, 2.6 MPa in the 850 mm tub and 10.6 MPa in the 420 mm tub. The control system will be based on that developed for LNEC with manual servo control.

A specification for the central arm services is being developed and this will be discussed with WES instrumentation engineers. The cabinets are expected to carry around a maximum of 200 kg each with 6 tension rods spanning between them.

Arrangements for the termination panels on the arm supported by the outer boom divider were discussed.

Priorities for appurtenances to be delivered during FY95 were considered. These will depend on the specification of appropriate experiments but may include:
1) an earthquake actuator;
2) a hydraulic flume;
3) groundwater control systems;
4) environmental liners;
5) wave actuator.

Training

The importance of developing an in-house training schedule was emphasised.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-117
Present:	RSS, RHL, P Hadala	Date:	28 April 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Progress on the centrifuge and appurtenance development was reviewed.

It was noted that a number of universities had expressed interest in collaborating with the project including:

VPI (with Professor Jim Mitchell)
University of Illinois
Texas A&M
RPI
University of California, Davis
Stanford
University of Maryland
North Carolina State
Vanderbilt

Joint research proposals were being encouraged.

Arrangements for acceptance of the centrifuge prior to shipping and inspection of appurtenances in Cambridge were discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-118
Present:	RSS, RHL, Lab Chiefs	Date:	28 April 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Geotech Lab, WES
Subject:	Briefing on centrifuge progress		

A briefing was held for the WES Lab Chiefs on the centrifuge project and the current status. The building progress was noted, together with the centrifuge programme and appurtenance procurement. The need for early identification of demonstration experiments by each lab was stressed, together with training and selection of engineers and technician staff to manage the facility. The building was inspected and it was agreed that early access to the control buildig was needed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-119
Present:	RSS, RHL, J Huie, D Banks	Date:	28 April 1994
		Time:	10.45 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

The meeting addressed the question of staffing for the new facility.

The following personnel and tasks were discussed:

Electrical engineer	electrical services and power, control and operation;
Electronics engineer	data aquisition, instrumentation;
Mechanical engineer	certification of experiments, design of appurtenances, containers, safety of centrifuge;
Technician support	handling of packages, assembly/disassembly of models, minor modifications, model making;
Manager	Direction, model design, marketing, staff management, centrifuge programme;
Secretarial support	

Several of these staff would need to be qualified operators. RSS to produce a list of tasks and duties needed for permanent staff. The forthcoming GL meeting was discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-120
Present:	RSS, ANS	Date:	11 May 1994
		Time:	5 pm
		Prepared:	RSS
		Notes:	Meeting at Reading
Subject:	Centrifuge progress		

The following points were noted for discussion with Acutronic:

a) ascertain the capacity of the hydraulic joints for air flow at 7 bar;
b) confirm the location of the required holes in the boom divider;
c) confirm the location of the required holes in the slip ring stack;
d) confirm RSS's visit on 2 June;
e) design of the termination panels.

KW and RNT will be requested to draft specification of the consolidometer and its control system for approval.

KW, Gopal Madabushi and ANS to draft final specification for plane strain box following consideration of possible dimensions and active thermal control system. Options for the loading actuator to be considered by KW for meeting on 17 May.

The thermal chamber is expected to be g limited with an 850 mm diameter internal chamber. Drawings are to be completed in time for the planned visit by RSS/ANS to CRREL in July. The tub will be enclosed within an air conditioned box to provide basic cooling. The specification for the cool air bath is to be prepared for 17/5/94 by KW/CCS/ANS/RSS.

The environmental chamber is expected to have a chemically inert lining with a 420 mm internal diameter and associated cool air bath. Specification to be prepared for 17/5/94 if possible and should be finalised by 20/5/94.

The data aquisition system specification from NB to be reviewed and agreed with RSS on 17/5/94 prior to discussion with WES.

Staffing at WES for commissioning of capabilities was discussed. The thermal chamber will be discussed at CRREL. The penetrometer and plane strain box will be discussed with GL at the meeting on July 21. It is anticipated that N Baker will make a series of visits and other engineers will be resident in Vicksburg for prolonged periods.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-121
Present:	RSS, ANS, KW, RNT	Date:	17 May 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Progress on equipment and appurtenances		

EQUIP-07: Consolidometer

Details of the specification were discussed. The support frame base area is to be 1.5 m square with 2 m clear height between the bottom frame and the top frame (allowing for 1.7 m of consolidometer rings and the loading frame). A safety statement may be needed.

EQUIP-08: Control system

The control system will be manually controlled without low pressure control. Low pressures will be accommodated by a second pump with lower compression ratio (5:1) than the high pressure pump (35:1). Monitoring will be by digital panel meter (DPM).

EQUIP-06: Plane strain box

Consolidation for the plane strain box will be carried out in a specially made 1200 mm diameter ring with stainless steel removable base (not designed for flight). Clay can then be consolidated directly into liners placed in the consolidometer ring, which are then extruded and cut by blades to suit. A liner support frame will be needed for handling in the laboratory.

The dimensions of the plane strain box will be 800 x 400 x maximum length to suit platform (probably around 900 mm). Options for the slab sides with and without windows would be explored. Service connections would be via a series of holes rather than through a single large port.

The side walls would be restrained by bars across the top. If a loading actuator was used, the base of the actuator would need to provide adequate restraint instead.

Concepts for an actuator were discussed, including the paper by McVay M. et al. on Centrifuge Modelling of Laterally Loaded Pile Groups in Sand (ASTM, 1993).

EQUIP-09: Central Arm Services

Dimensions and weights have been agreed. RSS will seek approval from Acutronic France for the tension rod location. It was proposed that the straps and rods should be sent to Acutronic for fitting. RSS would discuss with AFA the mounting of the units in Vicksburg.

The chassis plate loads have been sent to AFA and their comment is awaited.

RSS would discuss with WES the return of the penetrometer and control system for integration with the new systems.

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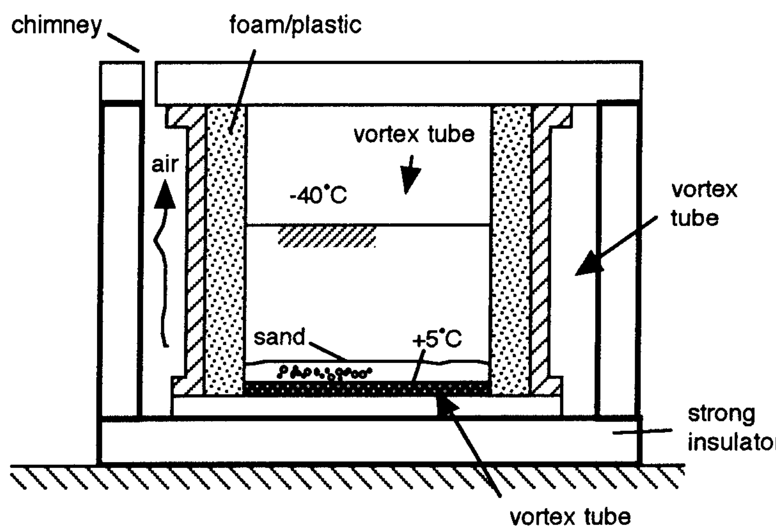
25-03-ROM-121 contd.

EQUIP-05: Thermal and environmental chambers

The environmental chamber (420 mm ID) will be held at constant temperature by a system based on vortex tubes. The inner steel chamber is enclosed within an insulated outer vessel, metal lined with a foam core. The inner face of the insulator may have fins to improve heat transfer. Waste air would be vented by a chimney. The inner chamber should have a maximum wall thickness and will be built from three rings (two plus an extension) bolted together. Their will be an anti-corrosion coating on the inside with a low friction finish. No liner.

The large thermal chamber is currently envisaged as 850 mm inner diameter with an inner liner fabricated from plastic rolled to suit and welded. The metal chamber would probably be designed for a maximum of 150 - 200 g and will be rolled and flanged. A thermal gradient will be achieved using vortex tubes initially to -40° C. The outer barrier will use an air-conditioned thermal box principle as developed for the 420 mm chamber.



THERMAL CHAMBER: CONCEPTUAL DESIGN

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-122
Present:	ANS, RSS, CC, KW, RNT	Date:	17 May 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Centrifuge progress		

Progress on each of the equipment contracts was reviewed and the following points noted:

1. Consolidometer

The Support frame area for the 150 tonne jack is to be 1.5 m square. Height to be 2m clear height between bottom frame and top frame (allowing for 1.7 m of rings plus loading frame). Safety statement may be needed.

2. Control System

Control system to be manually controlled without low pressure control. Low pressure accommodated by second pump (5:1). Monitoring to be using a DPM (digital panel meter). RNT will redraft the specification by 19.5.94

The downward hydraulic gradient consolidometer specification was considered acceptable.

3. Plane Strain Box

Consolidation is to be carried out in a specially made 12mm diameter ring with stainless removable base (not for flight). Liners are then placed in the consolidometer, clay consolidated in the liners, steel extruded and cut by blades. A liner support frame will be needed for carrying at 1g.

Dimensions of the plane strain box is to be 800 m x 400 m x maximum length to suit (probably around 900 mm) internal. KW will explore options for slab sides with and without windows.

Service connections will be via a series of holes rather than a large port. Solid walls will be restrained by bars across top. If a loading actuator is used, the base plate of the actuator will provide restraint. KW will review options for loading actuator. Work described by McVay, M Bloomquist, D Linde DV & Clausen J. Centrifuge modelling of laterally loaded pile groups in sand ASTM (1993) was noted.

4. Central arm services

Dimension and weights were agreed. RSS to seek approval from AFA for tension rod location and propose that straps and rods are sent to Acutronic for fitting. RSS to discuss with AFA monitoring of units in Vicksburg. Progress awaits RSS actions. Chassis plate loads have been sent to AFA and approval is awaited.

RSS to discuss with WES whether the penetrometer can be returned to Cambridge for integration with new systems.

5. Thermal and environmental chambers

Environmental chambers (including the small tub 420 mm ID) are to be held at constant temperature using vortex tube technology. The inner steel chamber is enclosed within an insulated outer vessel, with metal lining and foam core. Inner face of insulator may have fins to improve heat transfer. Waste air is vented by chimney.

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ROM 25-03-ROM-122 contd.

The inner chamber should have maximum wall thickness and will be in three rings (two + extension) bolted together. Anti–corrosion coating on inside with a low friction face and no liner.

Thermal chamber

Anticipated to have an 850mm inner diameter liner fabricated from plastic rolled to suit and welded inside a metal chamber designed probably for a maximum 150–200g (rolled and flanged). A thermal gradient will be achieved by vortex tubes initially to –40° C. Outer barrier uses air conditioned thermal box principle developed for 420 mm and other chambers.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-123
Present:	RSS, ANS	Date:	20 June 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Centrifuge progress		

1. Central arm services

The programme for mechanical design and fabrication of central arm services depends on Acutronic deadline for machine assembly. The nature of proof tests for machine need to be determined soon because of requirement for an agreed programme of commissioning tests and handover. Data logger and training programme for the Schaevitz to be discussed in USA.

2. Penetrometer and drive amplifier.

RSS to arrange shipment back to Cambridge.

3. Specifications

Colin Smith and Gopal Madabushi to complete their specifications. RSS to review and accept CAS and consolidometer specifications shortly.

4.Programme

It was anticipated that from the end of January 1995 activities in WES would include wiring and proving of systems. Need training to be provided during assembly for WES engineers. Formal commissioning tests will require senior ANS & A and WES staff to be present. RSS will discuss with WES reliable Mechanical/ Electrical companies which are local and can provide support.

5.Commissioning tests

ANS&A need to develop a logical programme to build up use of the appurtenances and demonstrate capabilities.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-124
Present:	RSS, RHL	Date:	24 June 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

General

Discussed specification for central arm services and agreed that this would be discussed further during the planned visit in July by RSS, ANS and Neil Baker.

Concerns over the quality (porosity) of concrete in mass concrete pours and in the floor of the chamber were noted.

The list of experiments proposed by staff from Geotech Lab were discussed. Staff who had submitted proposals included:

M Al-Hussaini
Paul Albertson
Don Alexander
John Anderson
Walter Barker
Dave Bennett
Joe Koester
George Mason
James May
Paul Miller
W O Miller
Marian Rollings
Ray Rollings
Don Smith
Lawson Smith
Tim Vollar
Don Yule

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-125
Present:	RSS, RHL, R Whalin,	Date:	24 June 1994
	WES staff	Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge containment structure		

General

The nature and quality of the concrete in the floor and mass foundation of the containment building was discussed with experts from the Concrete Laboratory. The concrete in the floor appeared to be gaining sufficient strength to meet the specification despite test results from the contractor which had raised concerns.

The entrapped air exceeds the specification in one or two cores tested by WES from the floor slab. The significance of this in view of the cyclic loading of the foundation was discussed. It was noted that strength tests on the mass concrete seem to be acceptable.

Possible approaches to the contractor to ensure acceptable testing of the remainder of the structure were discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-126
Present:	RSS, RHL	Date:	25 June 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

General

The forthcoming visit to CRREL by ANS and RSS was discussed. It was anticipated that the visit would be on the 19 July and would be followed by a visit to WES and an open meeting for interested parties from Geotech Lab on 21 July.

Neil Baker would travel directly to WES and be available on 21st also.

Thermal/environmental control

The concept of active thermal control using vortex tubes and a specialised container was discussed.

Acceptance Test Plan

The draft of the Acutronic Acceptance test plan No 6029 was reviewed and ANS&A's concerns over omissions concerning any reference to stress and strain measurements, dynamic response or nature of applied loading for proof tests were noted.

The use of ANSYS to analyse the platform during the commissioning tests was discussed. To options were considered: firstly ANSYS-PC could be supplied as part of the data aquisition system enabling check-outs to be made in Cambridge prior to shipping. Alternatively a conversion could be made from the ANSYS model mesh supplied by Acutronic to a structural analysis code available in WES, perhaps via the KRAY network.

Resourcing

The following resourcing requirements were envisaged:

October 1994	Training of centrifuge users Training of model builders (technicians) Fitting out of control building and prep room Definition and design of commissioning tests Liason with outside bodies Instruction of engineers/management
January 1995	After arrival of centrifuge (probably late December) Installation of user systems Assembly of appurtenances/familiarisation Finalisation of control building Development of operational procedures
March 1995	Acutronic acceptance tests Inspection of operations Inspection of performance criteria Training of operators Installation of on-board systems

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25-03-ROM-126 contd.

May 1995	Post-acceptance operations Finalisation of operational procedures Initial tests Commissioning of capabilities
Fall 1995	Inaugural conference

Staffing requirements

Mechanical engineer	A search was in progress in WES to identify a suitable candidate. In the event that no engineer is found the ME could be provided by ANS&A for 2-3 years on contract basis;
Electrical engineer	It was anticipated that H Greer from ISD would provide a senior overview with technician support from ISD;
Program manager	It would be recommended that a program manager be appointed from the Fall '94 on a half-time basis;
Technician support	It was anticipated that at least two GL soils technicians would be made available;
Experimenters	D Leavell was suggested as a potential engineer experimenter.

Commissioning of capabilities

The sequence of tests to follow hand-over from Acutronic will depend on the priorities for the achievement of capabilities. For example a test sequence could be:

1. Blast in tub.
2. Use consolidometer to make clay sample.
3. Clay model, showing use of gantries.
4. Penetrometer and loading rams.
5. Silt slope in plane strain box.
6. Environmental chamber and flow.
7. Thermal chamber experiment.
8. Earthquake program.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-127
Present:	RSS, ANS, S Ketcham,	Date:	19 July 1994
	D Sodhi, CRREL staff	Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at CRREL
Subject:	Cold Regions centrifuge capabilities		

Objectives

The objectives of the meeting were defined as:

1. To determine the nature of the demonstration experiment to be carried out at WES.
2. To discuss current technology for the control of thermal environment in centrifuge model tests.

Experiments

A number of potential experiments were discussed:

1. Ice forces on rip-rap (prototype rip-rap typically 6" to 1 foot in diameter). Impact of ice sheet of varying thickness on shoreline. Transition in behaviour appears to be reached when ice sheet is of similar thickness to stone diameter. Rock fill slopes with well-graded aggregate were also of interest.
2. Ice sheet impact on offshore islands (constructed with sand fill) to study the ride up of ice sheets. For caisson protected islands experience suggests that around 10m of water is the limit for stable ice rubble protection of islands (deeper water does not retain the ice rubble).

WES centrifuge programme

The concept of temperature control in a centrifuge chamber by active control of model chambers was discussed. Vortex tube technology will make use of compressed air supply - a safe and simple approach in comparison with alternatives (refrigerants, liquid nitrogen etc). Techniques for modelling frozen ground have been based on crushed ice with models constructed in large domestic freezers, then tested with a freeze/thaw cycle. The concept currently proposed for the thermal chamber was described using lagging with a gap between it and the strongbox through which cool aor flows, scouring away the heat flow from the outer wall towards a central chimney. Inside the metal chamber a plastic liner will limit the heat transfer to the boundary walls. The upper and lower boundaries will then be controlled to the desired temperatures. The goal would be to create a model environment with the capability for slow temperature change. Fast temperature change is not expected to be achieved during the current work programmer because of the high temperature gradients required at high gravity. Further work is anticipated to solve this problem, perhaps using sprayed droplets of liquid CO_2 or liquid nitrogen.

The programme of experiments planned for commissioning and demonstration experiments was descibed. Handover is anticipated to researchers on March 15, 1995, although this may slip to May. The demonstration tests will then be run during the summer and fall of 1995. Training for researchers in centrifuge techniques should start in 1994.

A potential experiment for demonstration purposes could be the pulsing of cold gas upwards through a central vertical pipe in initially unfrozen ground.

CRREL

The small refrigerated centrifuge at CRREL was inspected and the current research programme,

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investigating frost heave in small samples was discussed. Load cells will be used to measure heave of the ground in the experiments.

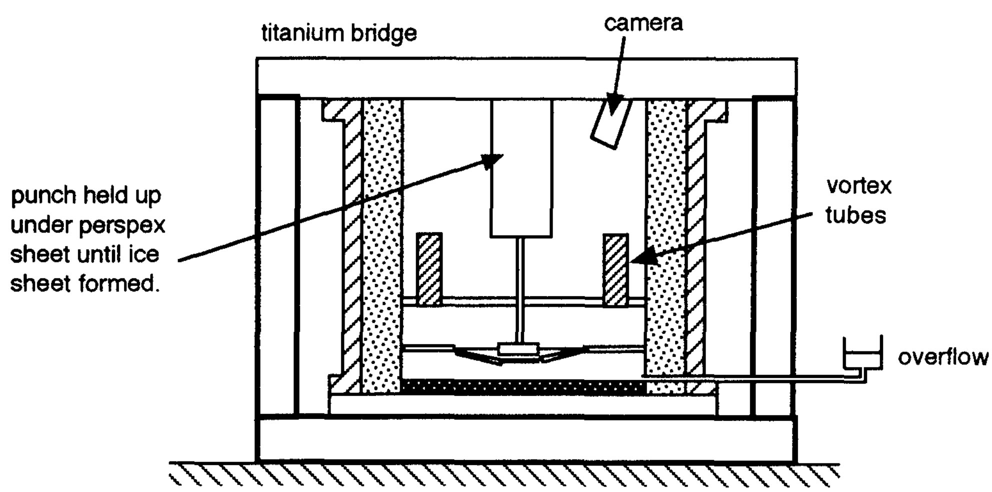
Future experiments

A potential experiment could be a combination of the above ideas if sufficient resources could be found to develop ground freezing technology. Surface footings, 2m diameter at prototype scale, could either be fixed with load cells or (simply) loaded with given lead weights and displacements measured. Several footings could be tested in the same experiment. Surface temperature control could be cycled ± 5°C. A link could be established with Professor Goodings at the University of Maryland building on her research for the Army Research Office. Careful coordination would be needed from CRREL, Maryland and WES to ensure compatibility of experiments.

An ice sheet model would need a free field of at least 60 x thickness to give appropriate boundary conditions, thus limiting ice sheet thickness to of the order of 1 cm. The ice sheet should bond to the walls. Under central loading using a circular punch radial cracks would be expected, followed by circumferential cracks and finally penetration. If the diameter of the punch is at least two to three times the ice sheet thickness then it would be expected that the ice sheet would fail in shear. To achieve a failure in bending would require a punch 4 - 6 cm in diameter. The outer diameter of failure would then be estimated as approximately d + 16H, where d is the diameter of the punch and H the ice sheet thickness.

Some experiments could be run at different g levels (eg 1 cm ice sheet) with the footing loaded by a screw jack. Ideally the experiment would be conducted using sea ice (which is more ductile than fresh water ice).

A typical configuration may be as follows:



experiment uses shallow water depths

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-128
Present:	RSS, ANS, Staff of GL and ISD	Date:	21 July 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting held at Hydraulics Lab, WES
Subject:	Centrifuge progress		

Meeting of GL to discuss proposals for demonstration experiments

The status of the centrifuge and the nature of the commissioning process was presented and discussed. Progress on the design and fabrication of appurtenances was noted.

The proposals submitted by GL researchers to carry out demonstration experiments were grouped under broad headings, eg pavements, earthquakes, geotechnical processes (slope failure), environmental processes, and the capabilities and limitations of the new centrifuge in each of these areas was discussed.

The following proposals were received:

to be completed

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-129
Present:	RSS, ANS, RWW, RHL	Date:	21 July 1994
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Staffing of the centrifuge

The urgent need to identify mechanical and electrical engineer/technician support for the new centrifuge was stressed. Shipping of the Acutronic centrifuge from France would follow the Factory Acceptance Test, which would be the first opportunity to see the machine fully assembled. It would clearly be important for the selected mechanical engineer to participate in that activity.

Training centrifuge

Operations on the training centrifuge were discussed; it was expected that this facility would form a valuable additional resource within the centrifuge laboratory once it became fully operational.

Commissioning of capabilities

The increasing interest and involvement of the different Laboratories in the commissioning of capabilities was encouraging. Good progress was being made towards the definition of the initial experiments which would be run by each Lab. The recent visit to Cold Regions was noted.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-130
Present:	RSS, ANS, P A Gilbert,	Date:	21 July 1994
	J Fowler, R D Bennett	Time:	3 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Schaevitz Training Centrifuge		

Meeting to discuss progress on Schaevitz Training Centrifuge

Progress had been made in the development of the training centrifuge and some experiments were planned for initial operations. The safety of the facility was discussed in detail and it was agreed that operation and use of the training centrifuge should follow standard procedures including formal approval of design calculations for appurtenances and detailed records of test 'flights'.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-131
Present:	RSS, ANS, RHL,	Date:	22 July 1994
	N Baker	Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Acutronic Centrifuge Acceptance Test Plan		

Meeting to discuss the centrifuge acceptance test plan

Acutronic's draft acceptance test plan was reviewed in detail and a number of important omissions were noted:

1. Control of operations during the acceptance test period

   The acceptance test period is likely to be lengthy, with formal approval for excursions to new ranges of operation only being granted by WES following careful review of all test results to date. During this period close control of the centrifuge must be exercised to prevent any operations being undertaken outside the current approved operating envelope. The acceptance test plan should clearly show the milestones by which initial operations gradually push back the operating envelope and the mechanism for control of those operations.

2. Verification of key design specifications

   No mention is made of the nature of instrumentation or the method of loading of the platform during flight to verify the specified platform deflection criteria and to demonstrate that no damage has occurred in operation. The method of checking the applied loads should be specified, together with the predicted response from the strain gauges.

3. Operating envelope

   This should be accurately drawn as this will be a key reference document.

4. Mechanical check

   The dimensions for components (such as the platform) indicate simply pass/fail. Record should be made of the actual measurements and comparison made with the specified tolerance. This is relevant to other parameters also, such as humidity and temperature gauges.

5. Design documentation

   The design documents should be included as a deliverable, checked at the time of the F.A.T.

6. Shroud

   No mention is made of the method of testing of the shroud.

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7. Operation

The long-term test proposed is inadequate. A test of at least 36 hours should be specified at maximum speed under full load. Checks should be made of cross-talk in the electrical slip rings and the performance of the hydraulic rings under g. Drift of the centrifuge g level during operations should be checked. Temperature and humidity of the chamber should be recorded during all tests. An independent speed check should be made. Manual operating mode and alarm sensitivity should be checked. A ramp-up test should be specified.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-132
Present:	RSS, JP	Date:	27 July 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes and TLM
Subject:	Centrifuge progress		

Platform

The platform was in the process of being welded and heat treated. The honeycomb structure of the base slab had not yet been sealed. All welding is carried out under the control of the Institute de Soudure. The standards of manufacture were discussed and it was noted that a welding test plan and manufacturing notes are submitted as part of the drawings for assembly. (The Quality Control Book delivered with the centrifuge includes all certificates and manufacturing notes.)

Shroud

Stress checks on the shroud are currently being recalculated by Acutronic to confirm the supplier's calculations. ANS&A to request clarification of these computations from Acutronic, particularly on buckling checks. It was noted that the failure of the Kajima shroud had been due to running at 150g with a 40 kg payload.

Design book

ANS&A to review the current copy of the Acutronic design book and to discuss enhancements with Mr Gawad on a future visit.

Stress checks

ANS&A have discussed with WES the use of ANSYS, mounted on one of the centrifuge data aquisition system computers, to enable users to check loading on the platform prior to tests. Difficulties with converting the Acutronic FE mesh to the current version of ANSYS were discussed and it was agreed that Acutronic could help with the implementationof such a system if required.

Instrumentation on board

Strain gauges on the platform will be monitored through PC control at the centre of the arm. The data will be transferred via RS232 link to the centrifuge control PC which can interrogate the on-arm system remotely. These channels could be used for instrumentation if necessary. Gauges are planned for the booms and the hanger supports and will be glued during assembly. The control room computer can be used to monitor the gauges if the centrifuge is being operated under manual control.

The cost of a 1g loading test for the platform would be prohibitive but it is expected that data from the platform of the centrifuge in flight will be used to compare with ANSYS predictions. Acutronic will define the distribution of strain gauges and make recommendations in September.

Air conditioning of the building

Heat exchange in the building would need to transfer 1.2 MW . Mechanical refrigeration would double the

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Ref: 25-03-ROM-131 contd.

installed power to around 2.4 MW. Water cooling would have been cheaper but a very large area of heat exchanger would have been necessary.

Booms

Questions which had arisen in Cambridge concerned with equipment design were discussed. The spreading of the booms under load was noted to be upto 0.4 mm under maximum load. Drawings of the cabinets to hold ANS&A's central arm services were handed to Acutronic, together with drawings of the holes required in the outer boom divider.

Acceptance Test Plan

RSS proposed that the period following installation and prior to the acceptance test plan should be subject to defined operational procedures; however this did not appear to be covered in the present acceptance test plan as proposed by Acutronic. It was agreed that ANS&A would submit this and other comments in writing as soon as possible.

Visit to TLM

Following the meeting JP and RSS visited the manufacturer's plant at TLM, Franconville, in north Paris. Many of the components of the centrifuge were inspected and the programme for assembly was discussed with Acutronic and TLM.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-133
Present:	RSS, J Comati	Date:	24 August 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at TLM
Subject:	Centrifuge progress		

RSS and J Comati visited TLM in Franconville, Paris to inspect progress on the completion of the centrifuge components. The platform slab had been partially completed and it was agreed that each of the 'cells' would be numbered and photographed for future reference prior to welding of the cover plates. The quality of work appeared to be high and completion and assembly of the centrifuge was anticipated to be on schedule for the Factory Acceptance Test in October/November.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-134
Present:	RSS, K Wilkinson	Date:	6 September 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Equipment and appurtenances		

The 420 mm environmental chamber had been completed and was currently in Sheffield; it will then be sent to Cambridge for further testing.

Colin Smith is expected to complete the specification for the rectangular cold chamber this week. May use Liquid CO_2 under high pressure through slip rings. CIEL awaiting instructions.

Plane strain box

Stainless steel liner now ordered. Manufacture expected to be complete by Christmas.

2D Actuator

Will require combined vertical and lateral loading and unloading. Keith Wilkinson to respond to RSS on optimum capabilities. It was agreed that it would not need a cyclic capacity.

Consolidometer

The power pack had been ordered, expected by end October. A 150 tonne, 5 foot stroke cylinder has been ordered. The 1200 mm rings for consolidation and 850 mm piston to suit existing blast chamber rings are still to be ordered. The control system is on order with the power pack as a single unit with safety system. Neil Baker will be briefed on the control system.

On arm services

The adaptor unit will be sent to France during the first week in October. Expect to ship to TLM with correspondence to Acutronic. Cabinets have not been progressed. Neil Baker programming electronics.

Future equipment and appurtenances in Phase 3 (FY95) may include:

Earthquake shaker
Data acquisition Phase III
Upgrade to the consolidometer control system
Bridge & instrument trays
Instrumentation
Hydraulic systems/valves for control

A proposal would be prepared shortly.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-135
Present:	RSS, P van Laak, Centrifuge Coordinating Committee	Date:	21 September 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

A presentation was made by Paul van Laak from RPI of the RPI centrifuge development and shaker construction.

He described how commissioning of the RPI centrifuge had taken place in 1989 and an extensive experimental programme had since been developed. A 1 ton earthquake shaker had been constructed at an early stage for work on the VELACS programme and a new 12 ton shaker was now being commissioned. Servo–hydraulic systems for dynamic actuation at high g were expected to present few problems in principle but certain components such as the voice coil, which would be g limited would need to be redesigned.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-136
Present:	RSS, H Voss	Date:	21 September 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Telephone conversation
Subject:	Centrifuge progress		

The building handover was expected to be by 1 March 1995. Therefore the centrifuge would be shipped mid–January and to start installation mid–February. All construction work would be complete by April 1. Integration was expected to be complete in 4–6 weeks, hence the handover to ANS&A was expected to be in May.

In France the Factory Acceptance test was now expected to be mid November and it had been agreed that the centrifuge could be left at TLM until shipped in early 1995.

Dr Whelin or other WES staff would be welcome to visit anytime during October/November to inspect the work in France.

Concern had been raised over spurious power drops at the Station; HV agreed to investigate with AFA but initial reaction was that this would not be a problem for the centrifuge.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-137
Present:	RSS, RHL, N Deliman,	Date:	21 September 1994
	P van Laak	Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Mobility applications		

The meeting heard a presentation from N Deliman on the work of the mobility research group:

1) Mobility Factor Inference
Defence Mapping Agency (DMA) supply ITD information (Interim Terrain Data) and from this infer topography, vegetation. However, it is difficult to predict accurately the nature of terrain.

2) Stochastic Mobility Model
This is developed from ITD only given terrain factors, human factors etc. The NATO Reference Mobility Model (NRMM) predictions develop the ITD information with a stochastic model to look at the probability of terrain crossing based on different scenarios. Uses empirical field test data.

3) Robust Mobility Model
Addresses the fundamental mechanics of mobility; used for design/analysis with high computational requirements. Predicts vehicle/ground interaction.

4) Obstacle planning
OPS (software) predicts likely routes and then selects obstacle placement. Used in battlefield visualisation.

5) Logistics planning
Movements of convoys, materials over different terrain; a specific programme coordinated with Coastal and Hydraulic is known as LOCS (Logistics over shore).

6) Mobility investigation
Validation of vehicle–terrain interaction relationships; support for vehicle acquisition.

7) Models and simulations
Distributive interaction simulation (wargaming) using speed profiles and engineer functional area models; virtual reality modelling.

Centrifuge applications

RSS described the background and objectives of the BAA and the centrifuge development. Applications in this field might use the 1.2 m square box currently being designed to operate between 20 - 350g. Most of the potential applications in mobility were expected to relate to pavement construction and loading but the shallow nature of the phenomena involved may restrict direct application of the centrifuge.

A potentially important area was however dynamic terrain modelling – studying crater effects. Crater formation was ideally suited to study in the centrifuge because it is largely gravity dominated. Such experiments could contribute to "Distributed interaction simulation" to study trafficability in the dynamic environment.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-138
Present:	RSS, RHL, R Welch,	Date:	21 September 1994
	P van Laak	Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Structures experiments		

Structures Lab were interested in continuing experiments on crater formation including not only photography but measurements of the flow-field using velocity and stress measurements. The use of PVDF gauges and pore pressure gauges was discussed. It was noted that the frequency response of pore pressure transducers would need to be checked but in principle they were an ideal device for detecting soil shearing.

The first experiments of interest are likely to be in the area of rock geology: validation of explosive modelling in jointed rocks, probably using simulated materials: steel, plastics or microconcrete.

It was greed that further discussions on the high speed data acquisition systems would be needed shortly.

"Microscaling" was a goal for future structures research – to put experiments into the office rather than out in the desert. The centrifuge fitted well into this strategy.

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RECORD OF MEETING

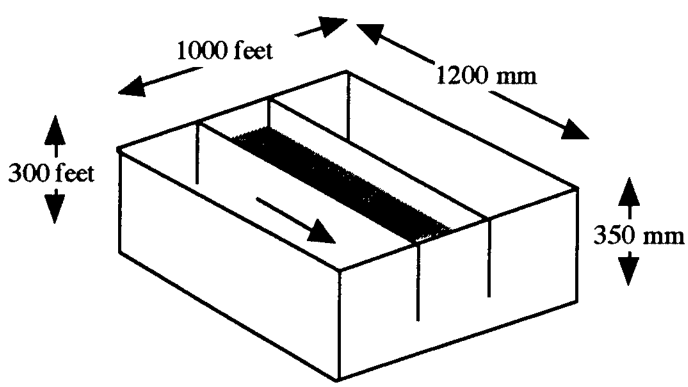
Project:	WES	Reference:	25-03-ROM-139
Present:	RSS, RHL, Coastal Lab staff,	Date:	21 September 1994
	P van Laak	Time:	3.30 pm
		Prepared:	RSS
		Notes:	Meeting at WES Coastal Lab
Subject:	Coastal experiments		

Don Ward was expected to act as the researcher to complete the demonstration experiments for Coastal Lab. Options include explosive generated waves, flow through rubble mounds, sediment transport.

Discussion addressed the problem of modelling transmission through breakwater which requires Froude scaling of waves and Reynolds scaling in the interior of the dyke. Not many new breakwaters are built today but many are being repaired or sealed and this would be the purpose of this research.

Current area of physical modelling include wave agitation in harbours (Froude scaling only); sediment concentrations (at prototype scale) using U tubes; mooring forces (in connection with US Navy).

Possible applications of the 1.2m square box were discussed.



A valuable demonstration experiment could be of the Supertank–type, used for the calibration of GENESIS or S–BEACH, using the advantage of the higher frequency of wave generation in centrifuge scaled model.

Instrumentation would use laser–doppler through fluid, wave guides for surface measurement or acoustic velocity measurements. OBS (optical back scatter), used for measurement of sediment concentration, uses laser light.

Jane McKee Smith described the nature of the Supertank: 15' wide, 15' deep and 300' long. It could develop 4 or 5' waves with a period of 8 to 20 seconds (top) at prototype scale. It was used to study problems such as reshaping of beach sand over a season. The pinch–off depth is related to the equilibrium slope (eg a 2' wave generates no activity in a depth around 3 times the wave height). Around 10 gauges would normally be located in the swash and 16 out to sea. The period for the experiment to come to equilibrium was typically less than 20 hours.

A high frequency transponder is used to measure the velocity in fluids by acoustic techniques (eg the ADV–1 by SonTek).

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-140
Present:	RSS, WM III	Date:	22 September 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

RSS described the selection of experiments for the demonstration of capabilities and progress with the other Laboratories, eg layered soil profiles, dynamic terrain evaluation, and potential models for the collapse of voids or soft spots at depth.

The importance of manuals for the appurtenances and equipment, presenting the basis of the design and safety calculations, was emphasised. Draft manuals for the new appurtenances were reviewed.

Staffing requirements for the centrifuge centre (mechanical, electrical, instrumentation) were discussed.

Initial plans for the Inauguration of the centrifuge were considered. Options for the timing of an event were November 1995 and February 1996. Given recent information on building programme and expected late installation of the centrifuge, the February 1996 date would be preferred.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-141
Present:	RSS, RHL, P van Laak,	Date:	22 September 1994
	P Schroder	Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Environmental experiments		

RSS described the equipment development currently underway and ANS&A's ideas for research collaboration with Cambridge, particularly in the area of a capped dredge disposal experiment – studying the consolidation and stability of the cap and contaminant transport.

It was agreed that the PI from WES for this class of experiment was likely to be Mike Palermo. The contaminants for the experiment could be organics or heavy metals. Organics move slowly by diffusion/dispersion. However the Research Programme which had been anticipated to support the capped dredged experiment had been delayed and this might impact laboratory testing or computing costs for design.

If heavy metals were used these would probably be cadmium or lead. A paste (undisturbed sediment) would be ideal to demonstrate stability – probably a marine clay. Placement could be into a borrow area with a flat or mounded capping on the seabed (eg in Seattle). Caps are typically 3 feet thick. Erosion of the cap by wave action is a problem in the field but this would be addressed separately. It was noted that the concentration of contaminant in the surface water in a model could artificially distort gradients in cap.

The detection or contaminants by florescence may be possible and discussions with EL will be needed to clarify which metals can be detected.

The ranges of density/thickness of capping and stability of cap are parameters of great interest. Cracking alone may not be a problem if it can be demonstrated that the properties of cap will sorp the contaminant before it escapes.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-142
Present:	RSS, RHL, P van Laak,	Date:	22 September 1994
	J May	Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Groundwater modelling		

The meeting addressed potential models in the groundwater area (eg field problems at Rocky Mountain Arsenal or Aberdeen Proving Ground).

It was noted that these were complex problems where the groundwater has become contaminated. A clean up programme was being developed by WES using numerical models. Validation of these numerical models is necessary and has not been achieved to date.

However flow through clays is very difficult to validate in the field because of uncertainties in the geology and understanding of the flow mechanism. Recent experiments at Cambridge (and elsewhere) were discussed on the progression of salt water plumes into freshwater aquifers. Resistivility probes have been used to track the arrival of the plume.

The Aberdeen proving ground essentially comprises fluvial clays interbedded with sands and silts. Vertical flow of contaminants occurs as the tides move up and down. New models for flow are needed to deal with negative pore pressures in unsaturated zone (the nature of flow in unsaturated materials is still very uncertain). In contrast Rocky Mountain arsenal has steep hydraulic gradients to the river. Either or both of the field cases could form valuable centrifuge research experiments.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-143
Present:	RSS, Centrifuge Committee	Date:	20 October 1994
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Progress on the centrifuge was discussed; final assembly was now proceeding in Paris, and shipment was expected in January. However because of building delays handover was not expected until May.

The design of general packages (round and rectangular chambers) was discussed. Future options for a hydraulic flume were considered. Concerns were raised on the size of a flume for coastal work particularly in simulating Supertank experiment.

High speed photography for dynamics experiments was discussed, including still cameras mounted in the ceiling with high speed flash, the use of mirrors and mechanical or high speed video cameras on board, lighting arrangements and package design.

It was noted that the Inauguration conference will probably be held in February 1996 instead of November 1995 as earlier planned.

The development of capabilities during period May 95 – February 96 was discussed in detail. The current list of experiments comprises:

Lab.	Subject	Researcher (PI)
Coastal	beach profile changes	Don Ward
Environmental	capped dredge disposal (heavy metals)	Mike Palermo
Structures	underground experiment in rock dynamic terrain crater formation, eg using "Socorro Plaster sand" as commonly used for field experiments	Bob Welch
Hydraulics	groundwater flow (saline solution)	Stacy Howington John Peters
Geotech	silt slopes earthquakes dynamic terrain (mobility)	Vic Torrey Richard Ledbetter
ITL	soil structure interaction	Reed Mosher
Cold Regions	ice sheet penetration permafrost/frozen ground	Dev Sodhi Steve Ketcham

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25-03-ROM-143 contd.

A strategy for the gradual development of capabilities was discussed, based on the addition of complexities to models stage by stage (water, sand, sand and water, clay, layered models etc).

Support staff will be available: electrical and instrumentation, mechanical, geotechnical technicians/engineers. Several labs require to develop experience in sample preparation and a coordinated initiative may be necessary.

Materials selection is also important. Use of standard materials (such as Socorro plaster sand used by Structures Lab at Whitesands) would be the preferred approach. A list of all materials (soils, cements, silicon oil etc) likely to be in the Laboratory will need to be prepared for safety clearance.

Technician training programme may be set up with RPI for model preparation and instrumentation training.

A list of potential invitees to the inauguration is to be prepared by all groups by 1 November.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-144
Present:	RSS, WM III	Date:	20 October 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

A number of points were noted:

1) The involvement of other labs was being encouraged.

2) The Inauguration meeting arrangements need to be finalised.

3) The Training centrifuge was to be under the authority of Jerry Huie.

4) The 10' diameter surplus centrifuge is to be given to the University of Delaware.

5) Professor Roessett at the University of Texas at Austin has expressed interest in collaborating in the field of soil–structure interaction.

6) Staffing of the centrifuge facility was discussed, particularly in mechanical/geotechnical services.

7) Collaboration with Professor Kimura in Japan was discussed: WES expected to participate in Centrifuge symposium in Japan in 1997.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-145
Present:	RSS, RHL, Bob Welch,	Date:	20 October 1994
	Denis Rickman, Howard White,	Time:	1.30 pm
	Al Ohrt	Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Structures experiments		

Discussed the gas gun development at WES and the use of PPTs in blast experiments. It was agreed that 2 PPTs would be sent to Bob Welch.

The meeting heard a presentation on the 4' gas gun which was now operational at WES and used for impact experiments. The high quality and complexity of the mechanical engineering in the facility was noted and similarities with the need for high standards of safety and quality of engineering in centrifuge operations were noted.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-146
Present:	RSS, RHL, D Ward, D Resio,	Date:	20 October 1994
	D Davidson	Time:	2.30 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Coastal experiments		

Instrumentation for a wave experiment was discussed.

The wavelength at around 35g is expected to be around 1 cm amplitude with a period $T = 8/35$ seconds $\approx 1/4$ Hz. The depth of 6' in the prototype would be around 2 inches in the model. The length of flume is important; it was noted that a six foot flume would be preferable to the four foot flume currently proposed. It could be mounted on a support frame which was later used for stilling/recirculation.

The equipment envisaged includes:

a) a wave machine to make spectral waves;
b) wave rods (or other) to measure wave light;
c) velocity meters in fluid (at bed surface);
d) gauges to measure bottom bed profile;
e) optical back scatter gauge for the concentration of sediments.

Supertank experiment

Typically uses waves with a 3 – 8 second period and wave velocity = $\sqrt{gh}$ = 17.9 feet per second. The water depth at the toe of the slope is around 10' and the wave length varies between 60 and 143 feet.

Beach slope formation has two key parameters:

- the fall velocity of sand particle relative to wave height/period, and
- the shear stress on fluid bed.

By Stokes law it can be shown that the fall velocity increases by the number of gravities for the same particle and fluid and hence the fluid viscosity needs to be increased by N or the particle size reduced by $\sqrt{N}$ for similarity. The shear stress is expected to scale correctly if the viscosity of the fluid is increased by N.

Copies:	Signed

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-147
Present:	RSS, RHL, J Peters,	Date:	21 October 1994
	S Howington	Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Groundwater experiments		

The meeting addressed the nature of a demonstration experiment in groundwater flow modelling.

It was noted that many 1g experiments had been done. Research into multiphase flow (eg oil, water), however, is difficult at 1g unless the fluids are very close in density. From laboratory experiments properties based on capillarity can be deduced but only if the buoyancy is closely matched; now looking to link lab tests, model and field behaviour.

It is envisaged that a source generates a plume of fluid which passes through unsaturated, partially saturated and fully saturated phases in the ground; studies would address the nature of dispersion into the ground. Increased gravity enhances the effects of density difference. Research programmes are interested in predicting the effects of heterogeneities on the plume. The centrifuge models will need to account for variation in the flow field and should predict break-up and fingering exhibited by immiscible fluids.

Expect to also carry out 1g tests on models using miscible fluids to establish dispersive properties of the proposed centrifuge model. The plume could be silicon oil with a selected density, perhaps dyed if more than one source was used. Use of a point source will need to be considered, together with tracking its progress and later dissecting the model. The pore fluid could be water. An alternative would be to use multiple sources and study early and late time behaviour. The data is expected to be used to validate available numerical models.

It was agreed that RSS would send copies of papers and information on fluids commonly used in centrifuge modelling.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-148
Present:	RSS, RHL, R Whalin	Date:	21 October 1994
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

Dr Whalin was briefed on progress with different Labs in the development of demonstration experiments. It was proposed that ITL may not need a separate demonstration experiment.

The Factory Acceptance Test in France was discussed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-149
Present:	RSS, RHL, J Huie	Date:	21 October 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge progress		

The meeting discussed staffing arrangements for 1995, including arrangements for resident supervision of testing. It was agreed that proposals would be prepared for consideration by WES.

Equipment for FY95

Needed:

Earthquake shaker and instrumentation.
Wave tank with paddle for low g operation,
Data acquisition (dynamic)
Fluid control systems, reservoirs

Possible:

Inert liners,
Full window for plane strain box at low g
Base plate(s) for thick walled chamber (850 mm diameter)
Instrumentation (PPTs, accelerometers, etc).

It was noted that the programme for equipment delivery under the Phase 2 work was nearly completed. Equipment delivery is expected at the end of January.

The shipment of penetrometer back to Cambridge for integration with new control system expected imminently.

Copies:	Signed

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-150
Present:	RSS, ANS, CIEL staff	Date:	1 November 1994
		Time:	11 am
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Centrifuge progress		

Phase 2 equipment

Central Arm Services and cabling

It was noted that the frames for the central arm services had been shipped to TLM (RSS to notify Acutronic France). The lowspeed acquisition software was complete but the high speed data acquisition was currently under development. Cabinet supports outline design has been prepared: detailing still to be undertaken. Arm end termination panel was discussed: alternative concepts of flying cables, platted with support steel cables or pinned plates were considered (ANS/RSS to agree conceptual design). Long cables will be run from the Central Arm Services.

Consolidometer and control system

The manufacturing had now been ordered, including the 1200 mm tub and pistons (circular and rectangular) and frame. Two risers have been fabricated and will be machined but 850 piston postponed until FY95. The control system will be based on the LNEC design using Phoenix Hydraulics and is expected to be completed by the third week in November. Spare power supplies and tapping points have been provided for potential future upgrading to computer control.

Cold regions

Air conditioning system has been restored for temperature control. Outline design for square cold box with internal lagging and dry ice "black sky" will be proof tested in Cambridge. Detailed design will be straightforward. The environmental chamber 420 m tub has been completed and is now being proof tested at Cambridge with environmental experiments and temperature system.

Plane strain box

Detailed design now complete and manufacture will be undertaken shortly (with two liners). Expect completion by end of January.

Lifting systems need to be considered for manipulating equipment.

Bridge for instrument trays and penetrometer has been designed in titanium. Prices being sought for bridge and trays. Actuators still to be specified.

Equipment for FY95 was discussed. This would be likely to include:

1) Earthquake shaker (to be specified by RSS/ANS)
2) Data acquisition
3) Wave tank with paddle
4) Bridge
5) Instrumentation
6) Lifting frames/skates
7) Base, slab windows
8) 850 piston

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APPENDIX B

Draft Operating Procedures

for the Acutronic 684-1 Centrifuge

DISCLOSURE OF INFORMATION REGARDING MODEL TEST OPERATIONS

The intention of WES to create a world class facility, and to attract internationally distinguished visitors in many fields of activity to WES, may lead to a conflict of interest. On the one hand generally it will be of advantage to WES to receive expert comment and advice and therefore to disclose details of centrifuge model test operations to visitors. On the other hand in particular instances it will be in the national interest of the USA or in the local interest of WES not to discuss details of model test operations with visitors.

In all cases there must be full disclosure of all operations to one or more members of the WES Safety Audit team: in particular all blast, shock or other serious loading or toxic contamination must be kept under review by the Audit team and must be fully documented. In any case, where an item of equipment that is made available to a visiting centrifuge modeler has been subject to blast, shock or other serious loading or toxic contamination in the past, there must be a disclosure to the visitor of any matter which may jeopardise the visitor's project or themselves.

WES CENTRIFUGE OPERATING PROCEDURES

Approved:

1.0 POLICY AND OBJECTIVES

It is the policy of the centrifuge center to produce experimental data of the highest quality in accordance with the mission of WES, subject to the absolute requirement to maintain the health and safety of personnel, visitors or other individuals and the integrity of the facility itself at all times.

2.0 SCOPE

This document addresses the management and safe operation of the centrifuge center. The organization of the center is described, together with the operating procedures and guidance for centrifuge operations. Guidance for the preparation of stressing calculations is presented in Annex A. A sample Project Approval and test summary sheet Document is presented in Annex B. Guidance on the disclosure of information is given in above.

3.0 ORGANIZATION

Facility management

The management structure of the WES centrifuge facility comprises of the following personnel.

Director	The Director of the WES Centrifuge Center will retain overall responsibility for the facility and its operations, including the authorization of centrifuge engineers and modelers.
Manager	The facility Manager of the WES Centrifuge Center will be responsible for day to day administration and safety of operations, including the test programme.
Engineers	Engineers employed by WES who have sufficient experience of centrifuge model testing to give engineering approval to the tests of others, to train other users or operators, to operate the centrifuge themselves or to act as centrifuge modelers themselves. The approval of a pre-flight safety check will only be made by an authorised centrifuge engineer who is not also the centrifuge modeler.
Operators	Engineers or technicians employed by WES who have sufficient experience of centrifuge operations to advise and assist other authorised users, to verify test documents, to mount packages, to start the centrifuge and to undertake activities as directed by an authorised centrifuge modeler within an agreed programme.
Modelers	Research workers, engineers or visitors with sufficient experience of the operation of the centrifuge to propose and undertake programmes of approved model tests. It is the responsibility of the centrifuge modeler to prepare, and to gain authorization for, a preflight safety check.

The Director of the facility and the facility Manager are appointed by the Director of the WES Geotechnical Laboratory. The list of authorised engineers, operators and modelers will only include those with current experience and with a need for authorization; authorization will only be given by the Director of the facility. Names of individuals occupying these positions are listed in the Operating Manual, which is kept in the Centrifuge Control Room.

4.0 CENTRIFUGE OPERATING PROCEDURES

The preparation and approval of a centrifuge test, and the operation of the centrifuge are governed by procedures issued by the Director of the facility as directives to all staff and visitors. These are described below.

4.1 Procedure CP1
APPROVAL FOR CENTRIFUGE TEST

Glossary

PAD	Project Approval Document
Proof Test	A Proof Test is a test of any item of equipment to a loading condition 1.25 times the loading condition that will be experienced during the proposed test.
Standard Test	A Standard Test is a test where all items of equipment are subject to loading conditions less than 80% of their previous maximum value.

Procedure

Any individual proposing to undertake a centrifuge model test must produce and gain acceptance of a Project Approval Document (PAD) for the proposed test series.

Guidance

The PAD is designed to provide all relevant information pertaining to a centrifuge test series. The PAD must be approved by an authorised modeler and an authorised engineer. The PAD must contain:

a) a summary sheet giving the total mass of the package, the required counterweight location, the likely change in balance during the flight, the previous maximum g level, the services required and the flight programme. The summary sheet should include a copy of the centrifuge operating envelope showing the required operating level and identifying the status of the test (proof/standard test). The summary sheet will be signed by the authorised modeler and by an authorised engineer.

b) a flight manifest detailing all components of the model test equipment, their masses and centroid position. The likely change in balance during the flight for each component will be identified and the overall change in balance calculated. The manifest should be supported by sketches of the model test equipment clearly indicating the coordinate axes and direction of travel.

c) stressing calculations separately approved by an authorised engineer. Stressing calculations are not required for tests which are not classified as proof tests.

Guidelines for performing stressing calculations are given in Annex A. An example of a typical PAD is given at Annex B.

4.2 Procedure CP2
PROOF TEST

Glossary

Proof Test	A Proof Test is a test of any item of equipment to a loading condition 1.25 times the loading condition that will be experienced during the proposed test.
Standard Test	A Standard Test is a test where all items of equipment are subject to loading conditions less than 80% of their previous maximum value.

Procedure

The authorised engineer for any test will ensure that every item of equipment has been subject to a Proof Test in which it is loaded to 1.25 times the proposed test loading condition.

Guidance

A Proof Test is intended to provide a physical demonstration of the adequacy of the design stressing calculations and fabrication methods for the equipment by testing the entire package to a loading condition 1.25 times greater than the operating load condition.

Subsequent use of a test package at 80% or less of the Proof Test load are designated as Standard Tests and do not require to be supported by detailed stress calculations.

The classification of a test as a Proof Test or Standard Test is made in the PAD.

4.3 Procedure CP3
PROOF TEST OPERATING PROCEDURES

Glossary

Test Log	A record of all instructions undertaken by the centrifuge operator.

Procedure

A Proof Test will be carried out under the command of the authorised engineer, who will be present for the duration of the test.

The Operator will seek approval from the engineer for each instruction which will be recorded in the test log. At the end of the test the engineer will sign the test log as a true and accurate record of the Proof Test.

Guidance

The Test should follow a previously defined program of activities as detailed in the PAD.

The agreed program of activities may include a high g proof test of equipment followed by a slowing of the centrifuge to conduct a model experiment. If the centrifuge acceleration is reduced to 80% of the flight maximum or less and the engineer is satisfied as to the continuing safety or the facility the engineer may declare that Standard Procedures are to be followed for the remainder of the flight.

4.4 Procedure CP4
STANDARD TEST OPERATING PROCEDURES

Glossary

Procedure

The authorised modeler will inform the centrifuge operator of the location and availability of the authorised engineer prior to the start of each flight.

The centrifuge operator will follow instructions from the authorised modeler provided that these fall within the agreed flight programme and subject always to being satisfied as to the safety of the facility.

The centrifuge operator can stop the centrifuge at any time if there is cause to suspect a malfunction or to prevent an accident.

Guidance

Under Standard Test Operating Procedures the authorised engineer need not be present in the control room. However, it is required that the engineer be "on call" at all times for the duration of the test and therefore the modeler is required to inform the operator on the availability of the engineer during the test.

4.5 Procedure CP5 PRE-FLIGHT SAFETY CHECK

Glossary

Flight	Any powered rotation of the centrifuge.
Test	A proposed program of work defined in a PAD. A test may comprise one or more flights, scheduled or unscheduled.

Procedure

Prior to each test the operator will carry out the following procedures:

Flight Manifest

The operator will check that the weight of the all test equipment and the location of the fixed counterweights is in agreement with that stated in the Test Summary Sheet.

Authorization for test

The operator will check that the PAD relating to the proposed test series has been approved by the authorised engineer and will countersign the Test Summary Sheet.

Prior to each flight the operator will carry out the following procedures:

Loading of equipment

The operator will check that all test equipment is adequately secured onto the centrifuge.

Systems safety check

Immediately prior to centrifuge start, the operator will evacuate the secure areas, inspect the model and the centrifuge and check that the chamber is clear of loose objects. The centrifuge operator will note in the Test Log the details of the proposed flight, including the names of those present. The centrifuge operating systems will be checked and warning systems initiated as defined in the manufacturer's operating manual.

The operator will record in the Test Log that the Safety Check has been completed.

4.6 Procedure CP6
AUTHORIZATION OF CENTRIFUGE ENGINEERS, MODELERS AND OPERATORS

Glossary

Safety File	A file containing all information relating to the safe operation of the centrifuge facility.

Procedure

The Director of the facility will maintain a list of current authorised centrifuge engineers, modelers and operators in the centrifuge Operating Manual, which will be located in the centrifuge control room.

Guidance

The training of new Modelers, Operators and Engineers will be carried out under a defined programme of objectives. The most effective form of training will involve periods of formal instruction and periods during which trainees work alongside experienced Modelers, Operators or Engineers.

Centrifuge Engineers and Operators will be trained in accident and emergency procedures.

Refresher training will be provided as required, and in particular on each occasion when a change in operating procedures or new equipment is introduced.

Individual training records should be maintained as part of the safety information of the facility in the Safety File.

4.7 Procedure CP7
EMERGENCY RESPONSE AND CONTROL

Glossary

Procedure

An emergency which arises during the time the centrifuge is not operational will be covered by the general procedures for health and safety at WES.

The centrifuge operator will be responsible for taking the necessary actions in accordance with the WES health and safety directives in the event of an emergency which occurs while the centrifuge is operational.

Guidance

There are a large number of hazards associated with equipment and materials, some of which have been outlined above, which could contribute to an increased risk of accident. However human factors, such as fatigue brought about by the stress of long runs, may be equally serious in threatening the safety of the facility and must be considered carefully in any accident scenario.

4.8 Procedure CP8
INVESTIGATION OF INCIDENTS

Glossary

Incident	An event which raises concern as to the safe operation of the facility.

Procedure

All incidents which result in an accident, or could reasonably have resulted in an accident, will be investigated by a team appointed by the Director.

The findings of the investigation will be recorded and kept as part of the safety information of the facility in the Safety File.

Guidance

The Director of the facility should establish a system to ensure that agreed-upon actions which arise from the investigation are implemented.

4.9 Procedure CP9
AUDIT

Glossary

Procedure

The Director of the facility will ensure that an audit of the safety procedures is carried out periodically to ensure their effective operation.

Guidance

The interval between audits should not exceed three years. The Audit team will be appointed by the Director and their report will be kept as part of the safety information of the facility in the Safety File. A system should be established to ensure that agreed-upon actions that arise from the audit are implemented.

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Ledbetter, R.H., Steedman, R.S., Schofield, A.N., Corte, J.F., Perdriat, J., Nicholas-Font, J. and Voss, H. (1994) US Army's engineering centrifuge: Design, Proceedings, Centrifuge 94, Singapore, pp 63-68, Balkema.

Schofield, A.N. (1980), Cambridge Geotechnical Centrifuge Operations, Geotechnique 30, No. 3, 227-268.

ANNEX A

Stress checks for centrifuge equipment

GENERAL CONSIDERATIONS

Self-weight loading under high gravities is calculated on the basis either of the acceleration of each mass at its actual radius or on the basis of all masses at a nominal radius of 6 m for the Acutronic 684-1 centrifuge.

Calculations will assume that all containers are filled with saturated soil to their maximum working level and that this soil may become fluidised and apply pressures equivalent to a fluid of density 2100 kg/m^3.

Fluid reservoirs or supply lines should be assumed to be filled either back to the rotor axis and above or to their vent levels if they are vented into the chamber.

In general, then, the maximum g level for stress checking and equipment design will be 1.25 times the planned test g level. In circumstances where it is absolutely necessary to use the centrifuge facility or its equipment near to their maximum design capacity the regulations relating to proof tests will be adopted and the maximum g level for stress checking will correspond to the test g level.

Following the guidance above on self-weight loading, equipment design will be approved on the basis of calculations showing full plastic stress redistribution at the maximum design g level. Elastic calculations will provide valuable information on stiffness and deflections of equipment under high g but will be regarded as insufficient for the authorization of exposed equipment for testing.

The objective of the authorising engineer in this process is the prevention of secondary damage to the centrifuge facility through failure of equipment components. Plasticity calculations with a requirement for material ductility provide a safe and simple approach to stress checking, allowing for the detection of overstressing through deflection rather than through brittle fracture.

Standard properties for common materials and bolts to be utilised in stressing calculations are given in Annex A.

mild steel	specific gravity 7.83,	working stress 136 MN/m^2;
dural	specific gravity 2.82,	working stress 130 MN/m^2.

These working stresses, to be used with full plastic stress redistribution, include a safety factor of 2.5.

Bolts, such as Unbrako type, are considered ductile if not stressed above 30 MN/m^2 in tightening and are designed for 275 MN/m^2 under maximum design g loading. This working stress includes a safety factor of 3.5 . If highly torqued, to ensure a seal or friction joint, bolts must be discarded after 30 uses.

Where perspex is used for windows it must be secured by a metal frame with rounded edges not less than 6 mm radius. The perspex must be kept free from scoring. Under maximum design g loading perspex is considered to have a specific gravity of 1.3 and may reach 7 MN/m^2. This includes a safety factor of 2 and a stress concentration factor of 2. In other conditions the stress concentration factor may rise to 3.5 or greater and the working stress will be reduced accordingly.

The design of windows as flat plates will follow Roark, Young (1989). For example Roark Case 70 gives stresses and deflections in a flat plate under triangular loading with all edges fixed. For the calculation of deflection perspex will be assumed to have a Young's Modulus of 2.8 GN/m^2.

REFERENCES

Schofield, A.N. (1980), Cambridge Geotechnical Centrifuge Operations, Geotechnique 30, No. 3, 227-268.

Young, W.C. (1989), Roark's formulas for stress and strain, 6th Edition, McGraw-Hill.

ANNEX B

Project Approval Document
and
Test Summary Sheet

TEST SUMMARY SHEET

Package designation: **Page** ______ **of** ______

Proof test acceleration: **Date:** ______________

Required acceleration: **Test Code:** __________

Research Worker(s): ____

Brief description of test package

Package Mass	**Package Centroid**	**Counterweight Location**
(kg)	**(mm)**	**(mm)**

DOCUMENTATION CHECK AND AUTHORIZATION SIGNATURES
(tick box, sign and date)

- [ ] Check balance calculations ________________ ____________
- [ ] Check stress calculations ________________ ____________
- [ ] Check instrumentation / video ________________ ____________
- [ ] Check electrical services ________________ ____________
- [ ] Check air/hydraulic services ________________ ____________

Test authorization (refer to PAD 95/01 for details of test program)

______________________ ______________________
Centrifuge Operator Authorising Engineer

Project Approval Document
Commissioning Tests for US Army 684-1 Centrifuge

PAD Reference [95/01]

Project Leader [WES]

Authorising Engineer [ANS&A]

Research Organization WES Geotechnical Laboratory

Test Series Objective The aim of these experiments will be to establish the operating envelope of the Army Civil Engineering Centrifuge for inital operations.

Programme The following programme of tests will be performed.

	Payload	**G-level**
01	6 tonnes	150
02	4 tonnes	200
03	2 tonnes	250
04	8 tonnes	150
05*	8 tonnes	100
06*	6 tonnes	150

* denotes 12 hour duration test

The operating envelope established from these tests is shown in the attached figure.

In-flight Procedures Structural elements of the machine have been strain gauged. The locations of the gauges are shown in the attached figure. During each load run real time records of the strain gauge output will be logged.

Post flight Procedures After each test the following checks will be made

(1) Torque checks on pin tension bolts,
(2) Torque checks on feet bolts,
(3) Check accessible tolerances with feeler gauges.

The results of these checks will be recorded in the flight log.

Hazards	All flights to the operating envelope constitute a proof test under the operations procedures and require the attendance of the Authorising Engineer and Operator at all times.
Special Safety Needs	Refer to Hazards, above. The design of the payload will follow standard procedures. The mounting arrangements for the Central Arm Services will be checked before and after each flight and recorded in the flight log.
Equipment Design	The platform will be loaded with pre-formed weights. Each weight is approximately 1000 kg. A stressing calculation pertaining to the design of the weights is attached.
Slip Rings	No special slip ring configuration is required.
Central Arm Services	A balance calculation for the Central Arm Services is attached. Refer also to Special Safety Needs, above.
Instrumentation & Data aquisition	Strain gauge signals will be passed directly through the slip ring (after amplification) and logged on the portable datalogger. Thermocouple data will be recorded in a similar fashion.
Required Personnel	Project Leader [WES] Authorising Engineer [ANS&A] Research workers [WES] Centrifuge operator [WES]
Pre-flight Safety Check	Standard procedures will be followed. In addition, the centrifuge operator and the research workers involved in each test will each satisfy themselves that the platform is correctly loaded, and that all attachments are securely fixed. This will be recorded in the flight log.

Attached documents	Table 1	Package and Counterweight Locations
	[Figure 1	Operating envelope]
	[Figure 2	Strain gauge locations]
	[Attachment 1	Stressing calculations]
	[Attachment 2	Balance Justification Calculations for tests]
	[Attachment 3	Central Arm Services]

Project Leader (signed).. date..........................

This PAD and the attached documents have been checked and the work described in it is authorised to proceed:

Authorising Engineer (signed).. date ....

Table 1 Range of Masses and counterweight location

Test ID	Mass of Package (kg)	Centroid of Package (mm)	Counterweight Position (mm)

NOTES

[ ] = to be completed